THE GEOLOGY OF THE WARRUMBUNGLE MOUNTAINS.

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(Plates xxiv.-xxxii.)

Synopsis.

A. Geology.

1. Introduction.

The Warrumbungle Mountains proper lie about 70-80 miles W.S.W. of Gunnedah, and about the same distance N.N.E. of Dubbo, the two nearest and most convenient railway centres; and between the townships of Coonabarabran, Mundooran, Tooraweanah and Baradine, which are the nearest places where stores and accommodation can be obtained.

The Warrumbungle Mountain Region is roughly circular in shape, with a diameter of from 30 to 40 miles.

I spent two months in the district in 1905 (October and November) and nearly two months in 1906 (also October and

November), so that the observations here recorded represent field-work occupying a period of nearly four months.

During my field-work I derived much information about the country and cordial assistance from men stationed in the district. To Mr. Goodridge, Licensed Surveyor, I am particularly indebted for his never-failing courtesy and help. Dr. F. Failes of Coonabarabran, Mr. May-Steers (Stock Inspector), Messrs. John Knight, Senr., and Alfred Knight of Tannabar Station, Mr. Lawrence Brown of Tundebrine Station, Mr. J. Draper (Tundebrine), Mr. Goldfinch of Gowang, Mr. Wright (Road Inspector), and many others have rendered me valuable help. To Mr. A. Wallace I am indebted for his cheerful company on my first trip through the mountains. On my second trip I was accompanied by my brother, Mr. Thor Jensen, L.S.

Owing to the rough nature of the country, it was necessary to work this district by camping out in various places to which access could be attained with a vehicle, and making excursions on foot from the camps in all directions. During the work I have been camped at the following places :—Coonabarabran, Riversdale, Tannabar, Gowang, Uargon Creek, Tooraweanah, Tundebrine, Tēnandra, Goorianawa, Bugaldi, Upper Bugaldi Creek and Yarraman. By working from these localities it was found possible to visit all the most important peaks of the group and to acquire a good idea of its geological structure.

Work of a detailed nature has never been done in the district before, with the exception of Professor T. W. Edgeworth David's description of the diatomaceous earth and tuff-beds at Wandiallabah (Wantialable?) Creek.* The Rev. J. M. Curran has visited the district on several occasions, but has not published anything about it. Mr. Pittman and officers of the Geological Survey have made hurried trips to special localities in the region to report on mining claims, but have done no detailed geological work. To Sydney people the district is only known through the photographic zeal of His Honor, Judge Docker, who has done

* These Proceedings, 1896, p.264.

so much in this way to open up and make known the beauty spots of New South Wales.

Owing to the very characteristic physiography of the Warrumbungles, I published a preliminary note on that subject last year.*†

2. Petrography.

The rocks of the Warrumbungle Mountains fall under the headings Sedimentary, Pyroclastic, and Volcanic.

The *Sedimentary Rocks* consist of sandstones, shales, calcareous shales, conglomerates and recent alluvial. The Permo-Carboniferous System (Upper Coal Measures) is met with in most places E. and S.E. of the Warrumbungles, and consists of clay-shales, coal seams, sandstones, and conglomerates, which have, as a general rule, a dip to the S.W. of 1 in 20. Dolerite sheets or *sills* of pre-Tertiary age occur in connection with these rocks. In places we meet with mesas of sandstone of later (Triassic or Trias-Jura) age dipping N.W., and capping the Permo-Carboniferous, *e.g.*, Mow Rock, etc.; and cappings of andesite and basalt of Tertiary age are also common.

In the Warrumbungles proper, to the north of them (in the Pilliga Scrub), and north-east at Ulimambra we meet with sandstones and conglomerates which have, when not much disturbed by igneous intrusions, a N.W. dip of 5°-10°. These rocks have the usual barren look of Australian Triassic and Trias-Jura

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*These Proceedings, 1906, p.228.

†Since the above was written the Government Geologist, Mr. E. F. Pittman, A.R.S.M., has lately contributed a "Note on the Occurrence of Precious Opal at Tooraweanah, Warrumbungle Mountains," and Mr. Henry Deane, M.A., F.L.S., some "Notes on the Fossil Leaves from the Warrumbungle Mountains" to the last issue of the Records of the Geological Survey of New South Wales (Vol. viii., Part 3, 1907, pp. 187 and 189).

Mr. Deane's investigations show conclusively that the trachytic eruptions were of the early Tertiary age, for the tuffs in which the leaves examined by Mr. Deane are found occur sometimes interbedded with trachytic flows, sometimes overlying a trachyte flow and underlying a later basalt flow.

Both the above papers bring corroborative evidence for conclusions which I have come to in this paper.

formations. Naturally in the centre of the volcanic region dips are much disturbed. West of the Warrumbungles we find, at Tenandra, calcareous shales dipping W. at 10°—probably of Upper Trias-Jura or Cretaceous age. These too are intruded by andesitic eruptives (Tenandra Mountain) coeval with the Warrumbungle lavas.

At Scabby Rock, about 10 miles north of Coonabarabran, we find the trachytic knob surrounded by a narrow rim of highly inclined slates with quartz reefs, surrounding which we find gently inclined Triassic (or Permo-Carboniferous) sandstones. The slaty rocks are probably of Gympie (Carboniferous) age. (Figs. 4*a* and *b*).

At Timor Rock, about 8 miles west of Coonabarabran, fragments of chert are included in the trachyte. Several fine specimens of chert with *Glossopteris* (Permo-Carboniferous) were collected by Mr. McLeod, until lately schoolmaster at Bugaldi, near Wheoh Mountain on Upper Bugaldi Creek. I have been unable to find the outcrop, which is probably small, and brought to the surface by an igneous intrusion.

These occurrences, however, prove that rocks older than the Triassic occur at no great depth. One might also mention in this connection that at Tundebrine Station pieces of quartz and fragments of biotite granite have been brought to the surface by volcanic action.

The *Pyroclastic Rocks* consist of tuffs and breccias. Interbedded with them occur diatomaceous earths at Bugaldi, Yarraman, Wandiallabah Creek and Gowang. Tuffs and breccias of the arfvedsonite trachyte-comendite series were met with at Gowang, Wandiallabah Creek, Berum Buckle (Tannabar), Timor, Scabby Rock and Siding Spring Mountain. They occur very abundantly everywhere in the heart of the Warrumbungle Mountain group in association with the trachytes related to them. Andesitic and basic tuffs occur in association with more basic lavas on top of Mount Exmouth, at Chalk Mountain, Cow Mountain, Lion's Head, Paddy McCulloch's Mountain, and other

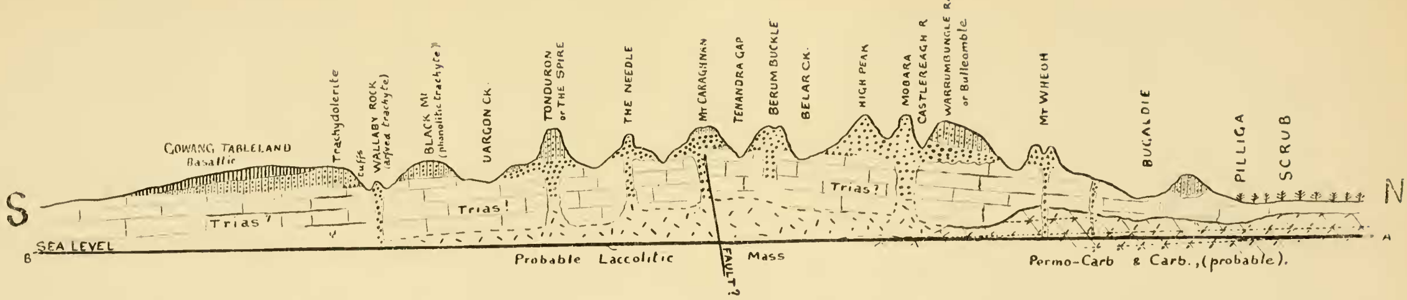

Fig 1 Section N&S along the line AB
WARRUMBUNGLE MTS (diagrammatic)

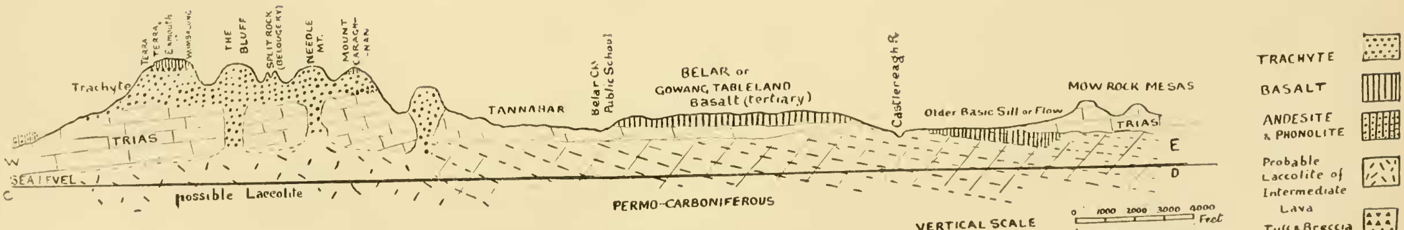

Fig 2 Section E & W along the line CD
WARRUMBUNGLE MTS (diagrammatic)

mountains round Bugaldi Creek, at Gowang and numerous other places.

The *Volcanic Rocks* include (a) light grey *arfvedsonite trachytes* which form the main bulk of the mountains in the heart of the group, such as Timor, Mobara, Siding Spring Mountain, Berum Buckle, Mount Caraghnan, Needle Mountain, The Bluff, Wombalong (Terra-Terra or Exmouth) and The Spire.

(b) Dark bluish *ægirine trachytes*, nepheline-ægirine phonolites and allied rocks, capping the arfvedsonite rock in places, as on Mount Caraghnan, and extending all round them in a sheet now dissected by gorges and wider creek valleys; the Warrumbungle Range north of the Castlereagh River from Timor to Coonabarabran is capped with this rock, as is also the ridge known as Naman Ledges; Tooraweanah Mountain, the Dillys (south of Tooraweanah), the Ridge Pole S.W. of Tannabar, Mount Tannabar and most of the spurs north of the Warrumbungle Range, such as Kalga Range, the Bugaldi Spur and the Yarraman Spur, have similar cappings.

(c) Grey nosean and pseudoleucite phonolites at Mount Bingy Grumble, Berum Buckle and round the base of Mount Caraghnan.

(d) Trachydolerite with sodalite, olivine, augite, ægirine and soda felspars at Uargon Creek covering much of the tableland south of Black Mountain, and forming part of The Spire pinnacle (Tonduron). The rock which forms the butte-like hills of the Forked Mountain and Nandi near Coonabarabran is closely related.

(e) Melilite basalts or basanites at Billy King's Creek, a couple of miles south of Coonabarabran.

(f) Sodalite basalt at Mount Gowang, The Spire, and other places, a differentiation-product of the trachydolerite.

(g) Ordinary andesites and basalts capping the other rocks in places, as on the top of Mount Wombalong (Exmouth), and spreading over a much wider area.

Sequence.—The sequence of the lavas seems to have been in general from the more acid to the more basic; and they merge into one another in such a way that there can be no doubt that they all belong to one rather long period of volcanic activity, probably, for reasons given later, lasting from the Eocene to the Pliocene. In the preceding paragraphs the lavas are mentioned practically in the order of sequence. South of Black Mountain basalts cap trachydolerites and are unquestionably the last outpourings. North of the Warrumbungle Range around Bugaldi basalts cap trachytic and phonolitic rocks. The age of the dark green or blue trachytic rocks (with associated phonolites) relative to the light grey arfvedsonite trachytes is harder to decide. At Mount Caraghnan there is a capping of the former on the latter; but more usually, excepting in the central mass of mountains, the light grey trachytes exist only as isolated knobs, either standing in a valley surrounded only by sandstone and occasionally

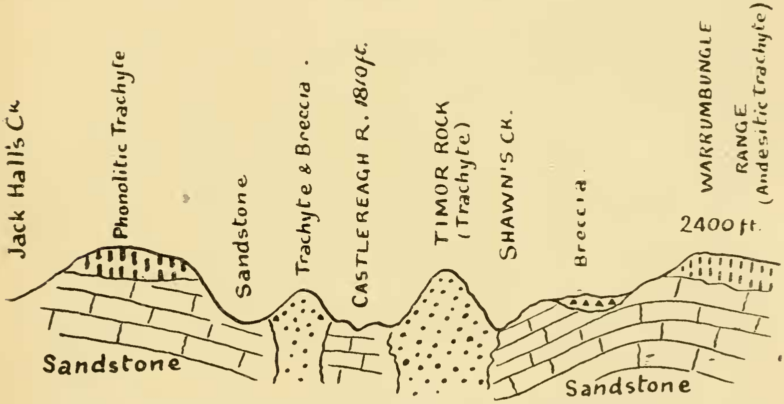

Fig.3.—Diagrammatic Section from the Warrumbungle Range to Jack Hall's Creek through Timor Rock.

tuff as Wallaby Rock near Uargon Creek (see Figs.1 and 5 *postea*), Scabby Rock (Figs.4*a* and *b*), Timor Rock (Fig.3); or surrounded by tuffs, and sometimes capped with basalt as at Gowang; or completely surrounded by the dark variety of trachyte, as Paddy's Rock in the Naman Ledges. This last kind of occurrence suggests that the more acid rock has been thrust into the more basic, a sequence which is not verified by occurrences elsewhere. The only explanation which satisfies all the facts is that the arfvedsonite trachytes were the earliest lavas and were in many cases injected into earlier tuff cones. Their maximum development was attained between Mount Wombalong, Berum Buckle and

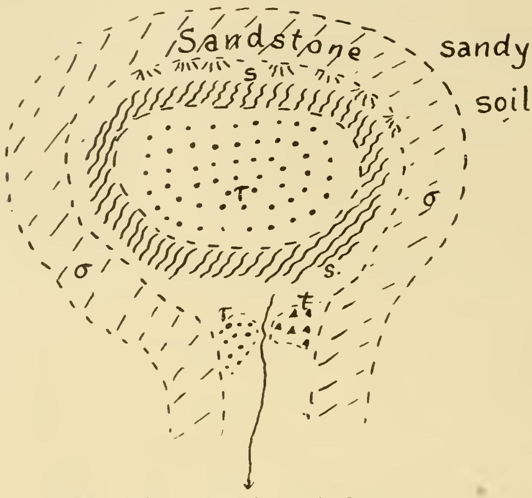

Fig. 4*a*.—Plan of Scabby Rock (diagrammatic).
r, trachyte; *s*, slate; *σ*, sandstone; *t*, tuff.

Mobara. Later flows of more basic lava followed, and this, being of a more fluid nature, filled the valleys around the central group and surrounded outlying members of the more acid series,

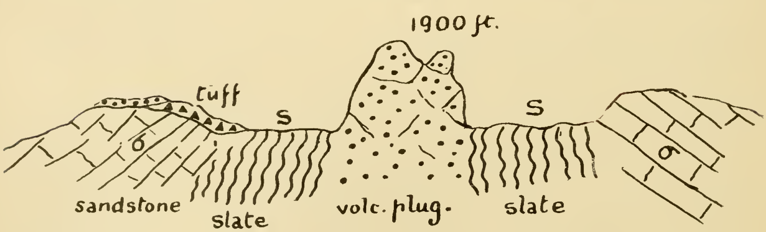

Fig. 4*b*.—Diagrammatic Section N. and S. through Scabby Rock.

forming an extensive lava-field sloping in all directions from the central mass. Subsequent erosion has carved valleys through this lava-field, reaching the sandstone below. The earlier arfvedsonite-trachyte plugs being surrounded by soft tuffs, have, in many cases, been isolated by the erosion.

Dykes of arfvedsonite-trachyte have been met with cutting the Triassic sandstones at Tannabar, behind The Spire, at Gibb's Pass and many other places, so that the earliest lavas are at least post-Triassic. Tuffs belonging to this series are, however, associated, at Gowang and Wandiallabah Creek, with leaves of *Cinnamomum Leichhardtii* and other leaves of Eocene appearance. This fixes the commencement of volcanic action as somewhere about the Eocene.

Distinct sills and laccolites I have not seen anywhere.

3. Physiographic Notes.

An observer standing on one of the central peaks such as Wombalong, Berum Buckle or Siding Spring Mountain, would observe (a) that the elevation of the mountains diminishes as the central group is receded from; and (b) that the watercourses pursue very direct paths outwards from the central group in all directions; when the streams reach the "plains" country they commence to deviate from their original straight courses. They are therefore "consequent."

The central mountains are very rugged. The surrounding zone of darker rocks is characterised by almost flat-topped mountains and ridges, sloping gently away from the central area. The watercourses are often wider inside the zone of dark trachytes than in it. Thus the Castlereagh River at Timor (Fig.3) has a wide valley, having had soft tuffs and sandstone to work in, but flows in a narrow V-shaped valley thence to Coonabarabran; Uargon Creek occupies a wide flat valley in the sandstone country north of Black Mountain and east of Tonduron, but runs in a narrow gorge between the Naman Ledges and Black Mountain (Fig.5). Wandiallabah Creek and Belar Creek show the same peculiarities. Where the creeks leave the inner sandstones and tuffs surrounding the light-coloured trachytes and flow through the hard ægirine trachytes and phonolites, erosion has not been able to widen the valleys at the same rate as higher up.

The Warrumbungle Mountains are drained by the tributaries of the Namoi and Castlereagh Rivers. The former is a consequent stream, throughout most of its course following the dip

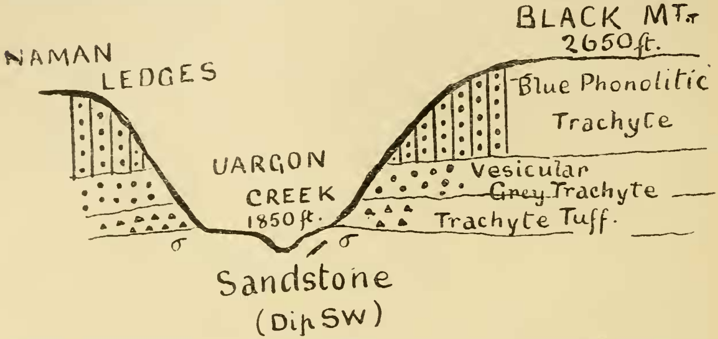

Fig.5.—Diagrammatic Section showing the structure of Goat Mountain, Tannabar.

of the Trias-Jura (or Trias) rocks in a N.N.W. direction. Probably it is a very old river, as Mr. E. C. Andrews has pointed out,* originating in its present course when the Triassic sediments were tilted in Cretaceous time. It follows that, where these sediments have been denuded away and the Namoi runs through Permo-Carboniferous rocks dipping S.W., it occupies a subsequent position, and is in reality a *superimposed* stream. In some places it cuts through deep alluvial plains of its own deposition, as at Narrabri. Many of its tributaries are *subsequent* streams running N.E., following the strike of the Trias-Jura. The Namoi is older than the raised peneplain marked by the mesas of Coonabarabran. The erosion produced by tributaries like Brigalow Creek, Baradine Creek, Bohena Creek and Bugaldi Creek has given rise to similar mesas of about the same altitude in the Pilliga Scrub, north of the Warrumbungle Range.

The Castlereagh rises in the Warrumbungles near Mobara. First it pursues an easterly course through a wide gorge or valley, with steep cliffs bounding it on the north. A few miles

* "Tertiary History of New England," Records Geol. Survey N. S. Wales, Vol. vii. 1903, p.27.

east of Coonabarabran it swings round and flows south, first in a narrow deep trough, later, about 10 miles south of Coonabarabran, in a shallow bed little below the level of the plain (Riversdale). Later, at Mundooran, the course swings to the west, and, still further on at Breelong, it takes a north-westerly direction which it preserves till the Darling is reached. Thus this river describes a spiral course round the Warrumbungles.

There can be little doubt that the drainage was more direct prior to the volcanic outbursts. There was probably a consequent stream draining the Liverpool Plains in the same direction as the Namoi and Macquarie. The great effusive pile of the Warrumbungles, however, effectively blocked it, and a new, more circuitous drainage-system had to develop. This accounts for the youthful appearance of the Castlereagh as compared with the Namoi. The poorness of the water-supply in the Castlereagh, and the development of *monkeys* (aboriginal "*moongies*") in its course I have already touched upon in my preliminary note.* Here, too, I mentioned how the creeks flowing westward from the Warrumbungles dry up, and have beds so little depressed below the general level that the traveller hardly notices when he crosses a creek. The drying up of streams on reaching the level country was also noticed in the Pilliga country. The water coming down from the mountain springs may be absorbed by the outcrop of porous artesian strata at a level of about 1,400 feet. Certain it is that the rainfall at the present day is insufficient to enable the streams to erode beds, but the existence of dry water-courses infilled with sand shows that at a remote period there was a better rainfall.

The watershed known as the Warrumbungle Range divides the drainage-areas of the Castlereagh and the Namoi. It commences as an offshoot of the Liverpool Range, east of Coolah, first runs N.W., then W., losing itself in the Warrumbungle Mountains to the N.W. of Coonabarabran; then it re-emerges as the Kalga Range at Bulloway Mountain. The Kalga Range

* These Proceedings, 1906, p.231.

runs N.N.W., gradually diminishing in altitude, until it is lost in the Pilliga Scrub to the N.W. of Baradine. The Warrumbungle Range has only an average height of about 2,000 feet, and is composed essentially of sandstones, conglomerates and shales which belong to the Triassic to the north-west and north of Coonabarabran, but to the east and south-east they probably belong to the Permo-Carboniferous (Upper Coal Measures).

The highest peaks of the Warrumbungle Mountains themselves attain an altitude of about 4,000 feet. In the centre of the group we have Wombalong (4,210), Terra Terra (3,710), The Bluff (about 4,000), Mt. Caraghnan (3,875), Berum Buckle (3,710), and Belougery Split Rock. Practically situated on the Warrumbungle Range, where it approaches most closely to the centre of the mountain group, are the high peaks of the Siding Spring Mountain (about 4,000), Mobara and Bulleamble. Mt. Bulloway, at the commencement of the Kalga Range, is apparently also about 4,000 feet high.*

The zone of table-topped mountains and spurs of dark trachyte and phonolite surrounding the central mass attains usually to the height of from 2,000 to 2,500 feet. Thus Timor Ledges, north of Timor Rock, are 2,400 feet high, Black Mountain and Naman Ledges 2,500-2,600, Gowang Tableland 2,200-2,500; Kalga Range, Paddy McCulloch's Mountain and the Bugaldi Ranges reach 2,000-2,500 near the Bugaldi-Tenandra Road, but drop to lower levels further northward.

In the valleys between the mountains are numerous smaller knobs, steep-sided plugs and sugarloaf-shaped cones. These are particularly abundant in the Gumin-Gumin Valley; Plate xxviii. illustrates their appearance.

The level at Coonabarabran is about 1,700 feet. At Riversdale, 10 miles or so to the S.S.E., it has fallen to about 1,400

* The elevations given in this paper can only be taken as approximate, being based on aneroid measurements checked by comparisons with the official barometric readings taken at Coonabarabran, for which I am indebted to the Postmaster. The altitude of Coonabarabran was taken to be about 1,700 feet.

feet. At Tooraweanah, to the S.W. of the mountains, it is about 1,500 feet; and at Tundebrine about 1,400 feet. At Tenandra Station it has fallen to about 1,100 feet; at Goorianawa Station the level is 1,200 feet; at Bugaldi it is about 1,350. Mundooran is about 1,000 feet above sea-level, Gumin-Gumin about 1,200, and Kalga 900 feet.

We see then that there is a tendency for the level to drop rapidly to that of the western plains around, *i.e.*, to about 900-1,100 feet. Around Coonabarabran there is a tableland elevated 400-500 feet above the Liverpool Plains to the S.E. Studded over this tableland are flat-topped sandstone mesas, and buttes of trachyte; the former all reach a level of between 1,900 and 2,000 feet—the same height as the Warrumbungle Range where it is composed of sandstone. The trachytic buttes, *e.g.*, Nandi, The Forked Mountain, Yarrighnan, Yarabala, etc., usually attain the same altitude, but frequently vary within wider limits. Very often trachyte caps a sandstone mesa, thereby increasing its altitude. The buttes and cappings represent remains of a sheet of lava which filled the valleys in the sandstone in the volcanic period. The lavas in the Warrumbungle Mountains proper overlie a continuation of this Coonabarabran plateau.

The foregoing description of the Warrumbungle Mountain topography with a glance at the reproduction of a stereogram (Plate xxv.) shows that the region has the nature of a lava conoplain, as pointed out in my preliminary note.

South and west of the mountain group we also find mesas and buttes which were originally portions of the Warrumbungle conoplain, but are now severed by erosion. Thus between Tooraweanah and Bearbung there are the Dillys, masses of sandstone with steep, often vertical walls, which overlie conglomerates (probably Permo-Carboniferous), and are in some cases capped with trachyandesite at a level of 2,000 feet. Similar masses occur north of the Warrumbungles in the Pilliga Scrub.

The soils are very different in different parts. In the sandstone belts they are poor and sandy, and characterised by pine (*Callitris robusta* and *C. calcarata*) and white gum (*Eucalyptus* *tereticornis* var. *dealbata*, and *E. coriacea* [?]) forests, with oaks (*Casuarina Cunninghamii*, *C. Luehmanni*) and belar (*C. Cambagei*) along the banks of creeks. In the arfvedsonite-trachyte region the soil is still poor, but somewhat better than in the sandstone country; pine trees are here typically absent. The dark trachytes and trachyphonolites have fair red soils, and are timbered with gums, ironbarks (chiefly *Eucalyptus siderophloia*), wattles, pine (*Callitris robusta*), emu-bush (*Eremophila* sp.), *Styphelia* sp., etc. The trachydolerites and basalts are surrounded by good red and black soils, commonly timbered with box (*Eucalyptus hemiphloia* var. *albens*) and a fair sprinkling of kurrajong (*Sterculia diversifolia*). Outside the mountain region we have the extremely poor and thirsty sandy soils of the Pilliga Scrub to the north, thickly timbered with pine (*Callitris calcarata*); and the vast black soil plains lying to the west and south-west. Interspersed with the black soil plains there are belts of wretched sandy soil of the Pilliga type. In some of the valleys in the mountains, as at Tundebrine and around Tooraweanah, where basaltic detritus accumulates, and where wash from basic trachytes is deposited, there are miniature black soil plains, in reality occupying the position of alluvial fans. From the close resemblance of the black soil in these valleys to that of the plains, in colour, touch, mode of cracking when dry, and vegetation it seems very likely that the black soil plains owe their richness to detritus brought down from the Warrumbungle Mountains in the course of ages. The black soil of the plains contains deposits of coarse gravels and waterworn pebbles made up partly of volcanic rock of the Warrumbungle type, and partly of quartz derived from the breaking up of the conglomerates. These coarse materials must have been carried down at a time when the rainfall was greater in the mountains than at present.

Wind-action is an important factor in redistribution in these areas, but as the winds here are mostly westerly, they have not taken any part in bringing down the detritus which formed the black soil plains. The wind, however, is an important distributor of pests. Almost every year produces a new variety of thistle, or other noxious herb, which completely monopolises the plains for the season, and only dies out to give the monopoly to a plague of something else. The winds bring the seeds from the west. The rabbit also helps the invader by shunning it for a while, and feeding on the diet he is used to. It is due to the rabbit that prickly species of thistles, unsuited for feed, are getting the upper hand on the plains.

The sandy soils of the Pilliga Scrub are, I am told, very deep in places, and must have been deposited partly by the aid of water in the rainy period, and partly by wind-action in the present arid cycle.

A striking instance of *natural pruning* is seen, throughout the Pilliga Scrub, in the uniform height above ground of the lowest branches of the pine forests.

Black soil plains are often devoid of forest trees. This is due mainly to the fact that they tend to become swampy in wet weather, and to scorch up, cake and crack in dry weather. Where the black soil is loamy, such trees as box (*Eucalyptus Woollsiana* ?), silver-leaved ironbark (*Eucalyptus melanophloia*), kurrajong, wattles and myalls are common.

4. Geomorphogeny.

(a) *Pre-Cretaceous Configuration.*—The Warrumbungle area was probably submerged in Carboniferous times, being the western margin of a sea which stretched across to the New England border. Elevation followed. In late Permo-Carboniferous times parts of it, especially the eastern and southern quartants, were depressed, and received sandy and gritty sediments (the Upper Coal Measures) probably from the west. In Triassic times the whole area was again submerged. The subsidence continued, with interruptions, until in Cretaceous time a movement of elevation or negative movement of the sea, probably connected with a general uplift in the Liverpool Range and New England, again made the area dry land. This uplift gave the Triassic sediments a N.N.W. dip, just as the uplift of the New

England area at the end of the Permo-Carboniferous gave the Upper Coal Measures a S.W. dip.

(b) *Stream-Development.*—In Cretaceous times the present drainage-system commenced, the rivers like the Namoi, Castlereagh (lower part) and the Macquarie taking a consequent direction, and flowing, therefore, N.N.W. The uplift continued for some time, but the rainfall being good, on account of a Cretaceous sea lying to the N.W., erosion almost kept pace with the uplift. Tributary *subsequent* streams like the Talbragar River, Baradine Creek, etc., now developed, and low watersheds like the Warrumbungle Range were formed by erosion. A stationary period following, allowed most of the country to be reduced to a peneplain, at present marked by the 2,000 feet level mesas all round the Warrumbungles. In the centre of the group there was a sandstone area which had not yet been quite reduced to a level, but was diversified with ridges and valleys. This takes us to early Tertiary (Eocene) times. Now volcanic action commenced, and the lavas built up the central mass to a great height; whilst subsequent outpourings not only filled up any valleys in the country around, but covered the peneplain over a considerable area with a lava-sheet thinning out away from the central mass. In this way it is possible to explain that some lava hills like Nandi near Coonabarabran, Yarrighnan and Yarabala near Bugaldi, rest on sandstone at a level of from 1,500 to 1,700 feet, being relics of flows filling valleys; whilst in most cases the lavas rest on the sandstone at a level of from 1,900 to 2,000 feet, being cappings on the old peneplain level (*e.g.*, cappings around Coonabarabran on the Warrumbungle Range, around Bugaldi, on the "Dillys," etc., etc.). In fact there seems to have been a slight uplift and recommencement of stream-dissection in the area before the ægirine trachytes, phonolites and basalts were poured out. This uplift was probably due to the injection of sills at the period of eruption of the arfvedsonite-trachytes.

The drainage of this area was now altered. The waters had to find their way round a great effusive pile. In this way the Castlereagh developed.

The late Cretaceous sea being now again dry land, the streams from the mountains deposited much of their silt on the plains, where the velocity decreased on reaching the more level country, thus giving rise to the Black Soil Plains. Valleys were carved in the volcanic conoplain, dissecting the lava-sheets and underlying sandstones. Thus the Castlereagh at Timor has cut through the phonolitic trachytes into the sandstones below. Likewise Uargon Creek flows between the vertical cliffs of Naman Ledges (a flow from The Spire crater, probably), and Black Mountain at a level of about 1,850 feet. At the 2,000-feet level on either side the sandstone is capped by lavas which the creek erosion has severed (Fig.5). In such cases the valley widens by the retreat of almost vertical cliffs, formed by the sandstone weathering away from under the lava-capping.

(c) *Peneplanation.*—As has been shown above, a peneplain, now marked by the 2,000-feet level, was formed at the end of Cretaceous time. Subsequent erosion has not produced another peneplain, yet the Coonabarabran tableland is approaching that end. However, the late Tertiary erosion has tended to reduce or base-level the land, not to sea-level, but to the level of the western plains. Following upon a wet period—probably Pleistocene or Pliocene, and contemporaneous with the lake period of parts of Central Australia, when an inland sea covered great areas—there succeeded a dry period, which still persists. This matter I have already touched upon in my preliminary note.

As evidence proving the existence of an *Arid Cycle** in the area of this Warrumbungle conoplain, the following facts are sufficient:—

(1) The streams have definite courses in the mountains where they are fed by springs, but dry up and become indefinite on reaching the more level country, especially to the north and west of the Warrumbungles.

(2) The country is being base-levelled to the level of certain depressions in the western plains, which have become filled with detritus (black soil) from the mountains.

* Cp. Journal of Geology, Vol. xiii. No. 5, July, August, 1905.

(3) The drainage is therefore disintegrated. The Castlereagh River itself is a striking example, with its dry beds and billabongs distinguished from the surrounding and more lowlying country only by a ridge of wind-blown sand (*monkey* or *moongie*). Many other creek-beds, no longer serving as water-courses, are present. Evidently in the arid period the integrated drainage-system established in the wet period has been destroyed. Old age of arid erosion has been reached in the country west of the mountains, and maturity on the Coonabarabran tableland. Only in the mountains themselves, on account of the hardness of the rocks, has a youthful appearance been maintained.

(4) "Scorched plains" devoid of soil, flat-topped stony hills, and slopes covered with coarse shingle instead of soil, have developed in the volcanic mountains; and around Coonabarabran a typical *bad-land* topography has been shaped.

(5) Alluvial fans occur in the valleys where declivity lessens, or where the streams reach the plains, as at Tundebrine.

(6) There are no post-Tertiary fossils, except a few plant-remains and bones of terrestrial animals, in the surrounding country. No marine or lacustrine Tertiary fossils have been met with either, so that there is reason to believe that throughout Cainozoic times land-conditions have prevailed.

(7) The Coonabarabran tableland, with its buttes and mesas, has the character which Passarge terms *Inselberglandschaft*, shaped mainly by wind-erosion.

Some of the above facts are also characteristics of a conoplain as defined by Miss Ida H. Ogilvie.*

The main reasons for looking upon the Warrumbungles as a conoplain may, however, be summarised in the following words:

(1) The mountains form an eroded lava-dome. This consisted of a high core of light grey trachytes, surrounded and capped by a sheet of phonolitic trachytes, which were again covered with later basalts.

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* "The High Altitude Conoplain." The American Geologist, Vol. xxxvi. No.1, July, 1905.

(2) The streams diverge from a common centre.

(3) The valleys widen by the retreat of vertical cliffs.

(4) Alluvial fans are common. Detritus is deposited all round the mountains where the grade diminishes.

(5) The watercourses frequently change their position; or the waters flow in a sheet when the plains are reached, following no definite course.

The rainfall in the Warrumbungles comes mostly in *heavy showers* separated by long *dry intervals.* This kind of rainfall favours arid erosion and conoplain-formation.

(d) *Vulcanism.*—The sequence of the lavas has already been described. Eruptions commenced probably in the *Eocene* period, and continued for a considerable time. The alkaline trachydolerites and basanites may have been as late as Miocene, and the calcic basalts which followed in places may be as late as Pliocene. Owing to the absence of fossils we have only the land forms to enable us to arrive at an approximation in this regard. The eruptions had finished when the very wet cycle commenced.

Volcanic action was throughout accompanied by elevation. The plugs and cones are not distributed along definite intersecting cracks as in the Glass House Mountains. If such cracks ever existed, their traces have been hidden by the enormous amount of lava poured out. Although the igneous mass occupies a somewhat circular area, there is reason to believe that the lava was erupted mainly from a fissure running N.N.E.-S.S.W., through Mount Wheoh, Siding Spring Mountain or Mombara, Berum Buckle, and The Spire (Tonduron). Berum Buckle at Tannabar is apparently the centre of the whole system. Radial cracks were probably developed, originating at this point. One fracture might be imagined running west through Caraghnan, Needle Mountain, The Bluff and Wombalong (Exmouth); another east through Goat Mountain and Bingy Grumble.

In the country around The Spire the sandstone nearly always reaches a higher level on the western side of a mass than on the eastern. This would seem to indicate that the lava came up diagonally from the west.

Possibly the weight of Mesozoic sediments to the west, after Cretaceous sedimentation, has contributed to squeeze underlying magmas away in an easterly direction.

The diagrammatic plan and section (Figs. 6*a* and *b*) illustrate the structure of The Spire, which is typical of that of many of the other plugs.

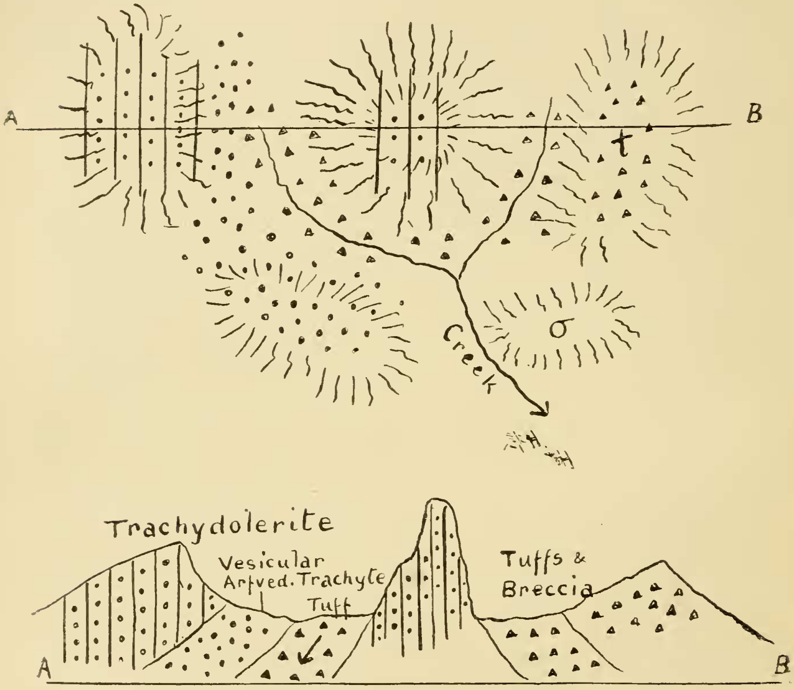

Fig. 6.—Diagrammatic Plan and Section of Tonduron (The Spire).

(e) *Present Changes.*—There are no indications of any oscillations or earth-movements in the present period. The Warrumbungle Mountains abound in poised rocks so delicately balanced that the least earth-tremor would cast them down. The well-known Bottle Rock, at Timor Rock, in itself shows that there has been no earth-tremor for thousands of years.

At present we have only the agency of erosion tending steadily by means of sand blast (wind) action, rainfall, etc., to reduce the mountains to the level of the western plains.

(f) *Remarks.*— The peneplain which developed in early Tertiary or late Cretaceous times, before the commencement of volcanic activity, may have been shaped by arid agencies like those prevailing at present. However, evidence in favour of this supposition is weak, and only of a negative character, consisting in the fact that we find no marine or estuarine fossils of Cretaceo-Eocene age anywhere within a very large area, such as we would expect on submerged parts of a true peneplain.

The slight partial dissection of this peneplain which preceded the phonolitic series of eruptions may, if the peneplain were of arid origin, have been due either to an uplift caused by intrusion of sills and laccolites, or by the development of an exterior drainage leading to a renewal of erosion.

The most puzzling problem met with in the field was that of the relative age of the light-coloured and dark-coloured trachytes. The structure at Timor Rock, which I have already discussed, and that observed at Paddy's Rock in the Naman Ledges opposite Black Mountain, where we have a mass of grey arfvedsonite trachyte surrounded by a narrow rim of tilted sandstone around which there are undisturbed flows of dark trachyte, may be explained in two ways. The neck of arfvedsonite trachyte may be imagined to be a plug which has filled the vent through which the ægirine trachyte rose and flowed over the country; or it may be imagined to be an earlier mamelon or neck surrounded by later flows of more basic rock. I have, however, nowhere seen arfvedsonite trachyte or its tuffs overlying the more basic rock in a flow or sheet. It reaches higher elevations, but either overlies sandstone or extends down to unknown depths. The more basic trachytes, however, have been noticed in numerous places capping the arfvedsonite trachytes in flows and sheets, as at Goat Mountain near Tannabar (Fig.7), Mt. Caraghnan and Uargon Creek, etc. *I have therefore come to the conclusion that the dark trachytes are the newest*, and that many of the ridges of this rock represent old valleys which were filled with it in the volcanic period. The old ridges, consisting of softer sandstone, have now become valleys.

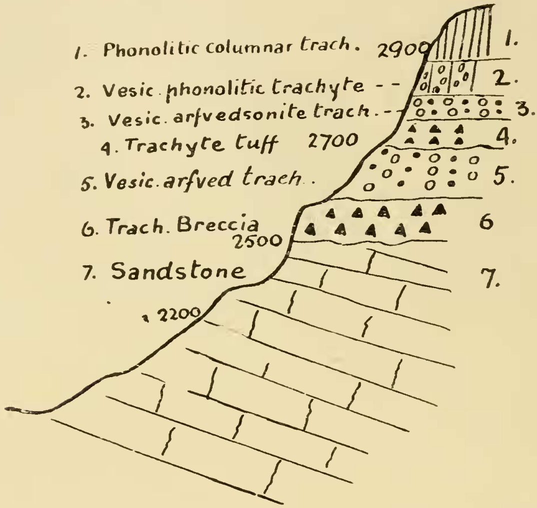

Fig. 7.—Section across Uargon Creek from Black Mountain to Naman Ledges.

The arfvedsonite trachytes have in most cases been necks injected into tuff cones. It is easy to understand that later erosion would find the soft tuff beds more subject to attack than the hard ægirine trachytes around. Consequently many plugs (or mamelons of originally viscous rock) stand now in valleys, their inaccessible walls forming a striking feature.

This view is borne out by the present structure of Tonduron (The Spire), which consists of a central plug of massive trachydolerite, and a number of high hills surrounding it, two of which (on the east and west respectively) attain mountain-like dimensions. These hills are remnants of the old crater-ring, and tuff and lava cone. The original mountain was built up of alternate layers of tuff and lava, with a plug of lava in the core. By the action of meteoric waters working along the soft tuff and breccia beds, the cone is being destroyed, all but the central plug. In the same way have most of the steep-sided monoliths been formed.

5. Springs and Artesian Water.

(a) *Springs.*—The fact that powerful springs with a perennial flow often occur on the summits of the highest mountains and very seldom in the valleys, has been the cause of much astonishment and speculation. I have heard the problem discussed by men of every occupation, from tramp to squatter, and from stockman to doctor.

Near the summit of Mount Terra Terra, at an altitude of 3,500 feet, I saw a powerful spring, which, during the drought, gave a permanent flow of water, and was the saving of much stock. Near the summit of Tenandra Gap two great springs originate at an altitude of more than 2,500 feet, and feed the heads of Wombalong and Belar Creeks. Below Siding Spring Mountain, on the south side at an altitude of about 3,000 feet, is the large and permanent Siding Spring; and on the northern side of the same mountain, at the same altitude, is another great spring, the Boonoo Spring I believe they call it. Then we have Wheoh Springs, Yarragrin Springs, Bulleamble Springs, and many others in the Warrumbungles.

Springs at the bases of mountains may be due to meteoric waters which have accumulated in wet seasons, and which escape gradually. Such springs would, however, not be permanent. They would weaken appreciably in a prolonged drought, and would show an increased flow in wet seasons. The Warrumbungle Springs, according to information received from numerous local station-owners and stockmen, show an increased flow in drought times, and a diminished one in wet seasons; but they never disappear entirely except to reappear close by. The waters are, therefore, of deep-seated origin.

The causes advanced in text-books to account for springs are (1) steam-pressure, (2) gas-pressure, (3) hydrostatic pressure, (4) pressure of overlying rocks.

(1) The springs show no evidence of being caused by steam-pressure, for none of them are warm; and volcanic activity has long been extinct in the region.

(2) Gas-pressure can hardly account for them in a primary way.

(3) Hydrostatic pressure cannot explain the phenomenon, for we get permanent springs on very high summits. They cannot be connected with the artesian system, inasmuch as they are above the artesian intake beds.

(4) Pressure of overlying rocks is a plausible explanation in some cases where the springs issue from sandstone beds underlying an igneous mass; but the increased flow in drought time, and the occurrence of springs on volcanic summits are facts which cannot be thus explained.

It seems to me that several of the above causes are in operation, but they are not the primary cause. The primary cause of these remarkable elevated springs is *rock-decay*. It is a well-known fact that most rocks contain, included in them, several times their own volume of gas, chiefly carbon dioxide and hydrogen, occluded in minute, ultramicroscopic cavities. In the same way they contain water. Decomposition liberates these substances; and in this way the gas-pressure necessary to force up deep-seated waters is produced.

In rock-formations like those of the Warrumbungles, rock-decay is particularly likely to produce great gas-pressure, inasmuch as the elements calcium, magnesium, and iron are not present in large quantities for the liberated carbonic acid to combine with. The most abundant rocks of the region are rather acid trachytes, highly alkaline and very low in lime, and highly siliceous sandstones and conglomerates. The latter are derived from older granitic rocks, and the quartz-veins are therefore, in all probability, studded with gas-pores. Most of the gas produced in disintegration of the rock must therefore escape.

In a prolonged drought joint-cracks widen, giving increased facilities for the atmospheric air to penetrate into the rocks.

This accelerates decomposition, hence increases gas-pressure, and produces a strong flow from deep-seated sources. This flow is the more powerful from the fact that the widening of joint-cracks and fissures has lessened resistance.

In 1902, springs were particularly active in this region. Personally I am inclined to believe that even the cause suggested above is inadequate to explain this, and that there was, as well, a great cosmic cause at work, the same which produced the violent volcanic activity in other parts of the world. Perhaps some such cause was, during the drought, causing slight folding; and hence increased rock-pressure in these parts.

It is interesting to note that in 1902, when the Namoi had become a series of waterholes, powerful springs broke out in the bed of the river in several places, causing it to flow for miles. In the same year remarkable cracks, big enough to swallow a cart, opened near Trangie, not far from Dubbo, quite suddenly, without any shocks of earthquake being felt, and gradually closed up again. These were in the Black Soil Plains, and may therefore have been due to desiccation; but I am informed that the occurrence was sudden. May it not have been caused by an earth-movement not of sufficient violence to produce appreciable shocks at a distance, and not felt locally on account of the thick blanket of loose soils on the plains (*cp.* the cracks formed in the Cachar Earthquake; see Suess, 'La Face de la Terre,' Ch. i.)?

(b) *Artesian Water.*—The following facts have been elicited by conversation with local inhabitants and by personal observation:

(1) Most of the Warrumbungle streams flow perennially in the mountains, but cease to flow on reaching the plains.

(2) They are supplied by springs at an altitude of from 2,500 to 3,000 feet or more.

(3) They cease to flow at an altitude of about 1,000 to 1,500 west and north of the Warrumbungles.

(4) Many continue to flow at a depth in the sand in their beds, or in billabongs filled with sand, for some distance, but more

disappear altogether. In the Pilliga Scrub it is generally useless to sink for water in or near a creek bed.

(5) Many of the wells and bores sunk in the district, at altitudes of between 1,000 and 1,500 feet, strike water which rises to a constant level, and gives a good pumping supply but does not overflow. This is the case at the Goorianawa bore and at many wells near Bugaldi.

The lower the altitude at which the well is sunk, the deeper one has to dig for water, and the higher it rises in the well.

These wells which maintain a constant level are evidently sunk in artesian or subartesian strata near the intake.

At still lower altitudes artesian water has been obtained by sinking deeper, and it overflows at the surface, as at the Kalga Bore and Tenandra Bore.

(6) In places on Bugaldi Creek a trickle of water has been obtained a few feet down. On sinking deeper, into soft sandstones, all the water has been absorbed, and no new supply has been obtained.

From these considerations we may deduce the following conclusions :—

(1) The Warrumbungle streams are supplied by mountain springs.

(2) The Artesian Intake Beds of the Triassic system outcrop at a level of from 1,500 to 1,000 feet to the north-west and west of the Warrumbungles. Hence streams disappear at this level, a feature which is partly brought about by the aridity of the plains.

(3) Bores in the intake beds give a permanent pumping supply but no overflow.

(4) A well in Triassic Sandstone may give a permanent pumping supply if cut through a pervious stratum into an underlying impervious one. On deepening it, one may cut into a second and lower pervious layer, and the well will dry up again.

(5) East, north-east, and south-east of the Warrumbungles, the formations are Permo-Carboniferous and Lower Trias, therefore

non-artesian. North-west, west and south-west the formations are mainly artesian, Upper Triassic, strata.*

For statistics concerning the output of the artesian bores near the Warrumbungle area, see Allan's paper.†

6. Diatomaceous Earths and other Minerals of Commercial Value.

(a) *Diatomaceous Earths.*—There are numerous deposits of this mineral in the Warrumbungles. Professor David described one occurrence at Wandiallabah Creek.‡ Here the earths are associated with trachytic (sanidine) tuffs.

Similar deposits in association with tuffs containing *Cinnamomum Leichhardtii*, *Endiandra præpubens* § and other leaf-remains occur at Gowang not more than half a mile from the station house at Keewong (or Gowang) Creek, and also on smaller tributaries of this creek and of Bianaway Creek. These last-named deposits are, however, thin and valueless.

A very thick deposit of good diatomaceous earth occurs on Chalk Mountain near Bugaldi. Its thickness is six feet or more, and it is interbedded with basic tuffs below which there is a sheet of phonolitic trachyte and above a sheet of vesicular basalt.

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* I am pleased to find that Mr. Pittman has also arrived at the conclusion that the trachytes in the west of the Warrumbungles overlie the Triassic intake beds of the artesian system. Mr. Pittman classes these rocks as Hawkesbury (Records Geol. Survey N. S. Wales, Vol. viii. p.187). In my Preliminary Note I called them Trias-Jura simply on account of lithological resemblance to the Trias-Jura rocks of South Queensland. I do not think any very definite evidence of age has so far been obtained, except that they cap the Permo-Carboniferous unconformably, and are of fairly late Triassic age. They also seem to me to merge into the Cretaceous to the north-west of the Warrumbungles without any unconformity, but this point is doubtful. The section of Tooraweanah Mountain in Mr. Pittman's paper is typical of sections met with in numerous places along Uargon Creek, Wandiallabah Creek, and at Gowang.

† Allan, P., "The Drought Antidote for the North-West, N. S. Wales," Proc. Sydney University Engineering Society, Vol. xi., 10th October, 1906.

‡ These Proceedings, 1896, p 264.

§ Deane, H., Records Geol. Surv. N. S. Wales, Vol. viii. p.191.

This deposit occurs about 650 feet up the mountain side at an elevation of about 2,000 feet above sea-level; it apparently extends under the entire basaltic summit of the mountain, outcropping on all sides.

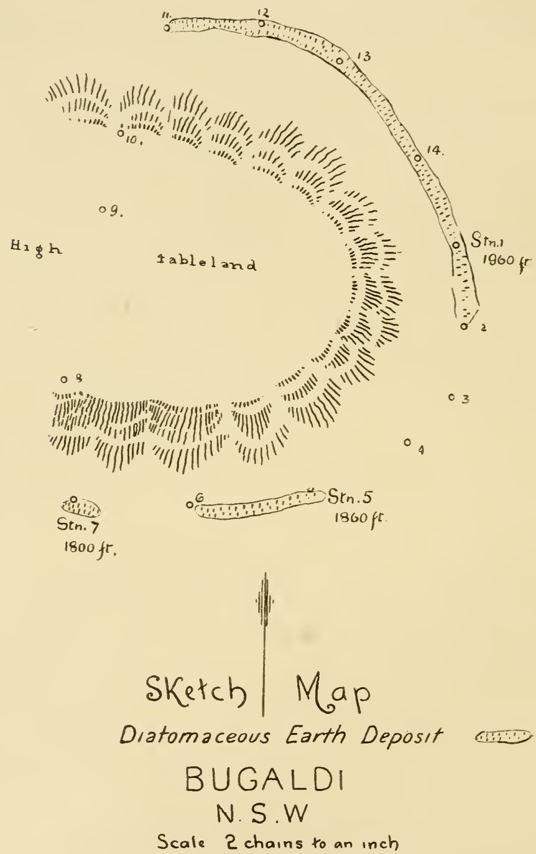

Fig. 8.—Sketch Map Diatomaceous Earth Deposits, Bugaldi, N.S.W. Scale, 2 chains to an inch (reduced by ½ approximately).

I have plotted the diatomaceous earths of Chalk Mountain in the accompanying figure (Fig. 8).

There are numerous other similar deposits in the vicinity of Bugaldi on other hills and also in some of the valleys.

On Paddy McCulloch Mountain near Yarragrin Springs, a similar deposit occurs at about the same altitude in similar associations.

Besides tuffs, petrified wood, petrified leaves and twigs, opal, silicified breccia and chalcedony are commonly associated with these deposits. From the associations we may judge that the diatomaceous earth deposits were formed in hot lakes and siliceous hot springs situated either in the craters or close to them.

Mr. E. J. Goddard has kindly examined the diatomaceous earths collected by me (a) at Wandiallabah Creek, (b) at Chalk Mountain, (c) at Paddy McCulloch, and finds that the material from each locality consists mainly of the common variety, Melosira. He writes:—"The earth collected from the locality of Chalk Mountain consists of the frustules of several species of Melosira allied to *Melosira crenulata* and *M. granulata*, both of which are well-marked European freshwater forms, and no doubt occur among our, so far poorly examined, diatomaceous flora at the present day. The genus Melosira is the characteristic organism of diatomaceous earths in New South Wales. In the diatomaceous earth deposit of Chalk Mountain the forms present are much larger than those from Wandiallabah Creek. Spicules of the freshwater sponge, Spongilla, are also present, but are by no means abundant as in the Wandiallabah Creek deposit."

Addendum.—In the trachyte tuffs of Gowang I have met with leaves or fragments of leaves belonging to the species *Cinnamomum Leichhardtii* Ettingsh., *Endiandra præpubens* Deane, *Anopterus Pittmani* Deane, and *Cryptocarya prœobovata* Deane.

(b) *Opal.*—Numerous seams of common opal, chalcedony, and allied forms of silica occur in the trachytes and associated tuffs. They are generally accompanied by silicified breccias, and petrified wood; and are probably the result of hot-spring action. I believe that there is every likelihood of good opal being found in some parts of the mountains, especially at the head of the Castlereagh, Wandiallabah Creek and Uargon Creek.*

(c) *Coal and Ironstone.*—I have seen specimens of good coal from a well near Croxon's, a few miles south of Coonabarabran. Whether it is of Permo-Carboniferous or Triassic age I do not know, but this part of the country appears to me to be Triassic. The Geological Survey Map has it Permo-Carboniferous. It is quite possible that payable coal seams may be met with.

It is of some economic interest too that there are throughout the area many ironstone beds in the sandstones. Some of these are so rich in iron that they will probably pay to work when the railway system reaches the district and workable coal seams are found.

B. Petrology.

Only volcanic rocks were of sufficient importance for the purpose of my research to be given special mention in this part.

In the present paper, as in my previous reports on the volcanic rocks of East Moreton, I have purposely avoided making microscopic measurements, by the Rosiwal method, of the amounts of different minerals in the rocks examined. Such determinations have (according to my experience in the study of the rocks of Prospect) great value when the rocks studied are coarse and even-grained, and consist essentially of easily recognised minerals. Then it is possible, by Rosiwal measurements alone, to obtain a very good idea of the chemical composition of the rocks. However, recent researches especially have shown that even in these ideal cases the method is inexact.

The rocks discussed in this paper are uneven- and fine-grained, and porphyritic. Most have a very fine base. It is therefore often impossible, without the very greatest expenditure of time and patience, to decide the nature of each grain. The results

* I have seen some very good fair-sized pieces of precious opal obtained at the head of the Castlereagh River near Timor, and numerous small pieces, the size of pinheads, obtained in vesicular trachyte in all parts of the Warrumbungles, and especially from the localities mentioned above.

arrived at are subject to doubt and uncertainty. The method in fact becomes painfully laborious and very inexact. When a knowledge of the composition of a rock has been desirable, I have therefore made a complete chemical analysis.

In my opinion microscopic study and chemical analysis are both equally essential for the correct description of a new rock. The former reveals, as accessories, minute crystals of fluor, apatite, etc., whose presence indicate traces of F, P_2O_5, etc., which might easily be overlooked in a chemical analysis. The latter, however, brings out clearly so many facts regarding the affinities of the rock that it cannot be dispensed with. The resemblance between the pantellarites and the comendites of the Glass House Mountains, and the trachytes of the Warrumbungle and Nandewar Mountains (*e.g.*, W. 16, N. 30, N. 59) is so close that a chemical analysis is essential to feel sure that there is a difference at all.

The Warrumbungle rocks may be conveniently classified under the following general headings :—

(a) Arfvedsonite Trachytes, Comendites and Pantellarites, light grey or bluish-grey in colour.

(b) Dark Ægirine Trachytes, Phonolitic Trachytes and Phonolites.

(c) Trachydolerites.

(d) Andesitic Rocks and Basalts.

The mineral contents of the first of these two divisions include felspars, soda-hornblendes, ægirine, ægirine-acmite, felspathoids like nosean and pseudoleucite, quartz (rare), decomposition-products, and apatite (extremely rare).

The felspar occurs with three different habits—the *orthophyric*, as in the Scabby Rock trachyte; the *prismatic*, as in Timor Rock trachyte; and the *tabular*, as in the silky trachytes of Gibb's Gap, etc., and the phenocrysts in the dark phonolitic trachytes. The prismatic habit is the commonest, being developed in the majority of the felspars of most of the rocks of these divisions. Tabular felspars are also very common. The orthophyric felspars are confined to the old plugs or necks. The prismatic type occurs both in the trachytes of necks and sheets or flows. The tabular type seems to predominate in the dykes, but occurs also in other rocks.

Orthophyric Felspars.—The felspar in the Scabby Rock specimens has the orthophyric tendency, although it is not quite isometric. The crystals seem to be usually enclosed by three sets of faces *c* (001), *y* ($\bar{2}$01) and *b* (010). Sometimes *x* ($\bar{1}$01) and *a* (100) are present. In some crystals the angles, as measured, show that the faces *m* (110) have developed to the exclusion of *b* and *y*.

Carlsbad twinning is not frequent, but Baveno twins in doublets and fourlings are common. Manebach twinning is rare.

At first sight this orthophyric felspar seems to be a water-clear sanidine, but on closer examination with high power a fine striation is noticed, in some sections both lengthwise and crosswise, giving a fine meshed appearance. Some crystals have an isometric core of unstriated felspar, probably true sanidine. The striations are due to microscopic twinning on the albite and pericline laws. The outermost zone is frequently pure albite. The felspars are therefore composed essentially of a cryptoperthitic intergrowth of orthoclase and albite or soda-microcline, occasionally with a core of sanidine and a rim of albite; the main bulk is therefore anorthoclase or microcline cryptoperthite.

The refractive index of all the crystals is lower than that of canada balsam. The optic sign is negative ($Bx_a = \mathfrak{a}$); the interference figure is, however, nearly uniaxial, and occasionally crystals occur which are positive in sign (albite): $\mathfrak{a}$ lies near a' and $\mathfrak{b} = c'$. The crystals are somewhat elongated along the *a* axis, so that sections parallel to *a* are square, and sections parallel to *b* and *c* are somewhat elongated parallelograms. Extinction is usually straight or nearly so in the direction of elongation, but of a shadowy nature in most cases, due to ultramicroscopic twinning. The extinction of the border zone usually varies slightly from that of the interior, the angle increasing from the interior outwards.

Prismatic Felspars.—The prismatic (lath-shaped) felspars so abundant in the other soda-trachytes of the area are much more fine-grained, so that it has not been found possible to determine them with accuracy. However, they agree with the orthophyric type in having the $\mathfrak{a}$ in the direction of greatest elongation, and in the extinction angle ($\mathfrak{c}$: a) in that direction being very slight (0°-5°). Carlsbad twinning is the commonest variety of twinning. Probably this felspar is also anorthoclase. It is the most abundant mineral both in the ægirine trachytes and soda-amphibole trachytes, and occurs as well in the trachydolerites.

Tabular Felspar.—This variety constitutes most of the phenocrysts in all the trachytes. It is tabular parallel to *c*. In other respects the properties are similar to those already described for the felspar of prismatic habit.

Inclusions of a black titanium mineral, pseudobrookite (?) or rutile (?), occur sparingly in the felspar phenocrysts.

Soda-amphibole.—This is scattered about throughout the rocks, bearing it in irregular fragments, few of which are large enough to give any indication of cleavage. In a few rock-types the grains are united into dendritic (poikilitic) aggregates. Sometimes the hornblende occurs in the form of *very dark*, *blue-black*, rod-shaped crystals and irregular grains. The absorption is greatest in the direction of the length of the rods, just as is the case in the prismatic riebeckites of the rocks of Mt. Conowrin in the Glass House Mountains, and Mt. Jellore near Mittagong.*

In the more decomposed specimens the grains and rods are replaced by a reddish-brown nonpleochroic mineral (*ferrite*).

In sections showing the two cleavages (at 56°), that is, perpendicular to the *c* axis, the colour changes from deep indigo-blue to blue-black, opaque, on rotating the stage. In sections parallel to the face *a* the pleochroism is from deep blue to greenish-blue, and parallel to the face *b* from greenish-blue to yellowish-green. The extinction angle is about 14° (probably *c* : $\mathfrak{a}$).

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* Taylor & Mawson, 'Geology of Mittagong,' Journ. Proc. Roy. Soc. N. S. Wales, Vol. xxxvii.

Probably the mineral is a variety of arfvedsonite. It commenced to crystallise after the larger felspars (felspar phenocrysts) had formed, and continued to crystallise until shortly before the last felspar of the base had consolidated. Hence we find felspar phenocrysts often enveloped by soda-amphibole and dendritic intergrowths of felspar and hornblende of the base.

This protraction of the period of crystallisation of the arfvedsonite was undoubtedly due to the action of mineralising vapours containing F,Cl,ZrO_2 and TiO_2.

Ægirine-augite.—In acicular crystals this is a very abundant constituent of many of the trachytes, particularly of the dark and phonolitic varieties. It is the sole ferromagnesian constituent of some rocks, but is associated with soda-amphibole in some, and with other pyroxenic minerals and olivine in the trachydolerites. It varies from highly pleochroic ægirine to almost nonpleochroic ægirine-augite. The latter is the dominant variety in the dark green trachytes and trachyandesites (W.1 Timor Ledges, W.117 Naman Ledges, and W.113 Tooraweanah Mountain, etc.). In these rocks it compensates with a selenite plate in a direction across the length, a being considerably removed from crystallographic c'; the extinction angle is mostly oblique at angles from 15°-30°; occasionally straight; the pleochroism is weak, in colours from yellowish-green to grass-green (with an occasional tinge of blue). The double refraction (γ-α) is about 0·030.

True ægirine and acmite are not well represented, but in most slides there are some crystals which can be referred to these types.

Felspathoids.—The felspathoid minerals identified in the trachytes are *nosean* and *pseudoleucite.* The chemical analyses prove that nepheline must also be widely distributed in the more basic types, although it was not at first noticed under the microscope. Staining tests confirm its presence. A more detailed description of these minerals will be given in the petrological descriptions of the slides in which they occur.

In the nosean and pseudoleucite phonolites the soda-amphibole tends to cluster round the felspathoid minerals. This seems to indicate that mineralisers abstracted SiO_2 and Na_2O from the felspar molecules, and at the same time added SO_3; the Na_2O they deposited in the ægirine-augite molecules with ZrO_2, TiO_2, F and Cl to form arfvedsonite; and the SiO_2 passed off as fluoride.

The other minerals sometimes, but not invariably, present in the trachytes comprise magnetite in primary idiomorphic grains, a very dull black or brownish-black mineral, probably pseudobrookite or rutile, minute zircon needles and more rarely minute stunted rods apparently apatite.

The order of consolidation generally followed was as follows:—

1. Accessories (magnetite, zircon, apatite, pseudobrookite (?), etc.)
2. Felspar
   (a) Orthoclase (sanidine)
   (b) Albite
3. Ægirine-augite
4. Soda-amphiboles

Nosean, when present, crystallised out early, practically simultaneously with the felspar phenocrysts; nepheline, when present, was one of the very last substances to consolidate.

This order of consolidation I will hereafter refer to as the *normal* order for these trachytes.

W.215. Loc.: Scabby Rock. (Plate xxx., fig.3).

1. Handspecimen: this is a light bluish-grey fine-grained rock which bears close resemblance to the Glass House Mountain comendites in handspecimen.

2. In microscopic texture it may be described as hypocrystalline, with a glassy interstitial matter cementing even-sized grains of the constituent minerals. The fabric is almost orthophyric.

3. Composition: the main constituent is *felspar*, most of which occurs in elongated prismatic and isometric grains. As already mentioned in the introductory notes on the minerals, it consists of microline microperthite (anorthoclase). Some of the crystals

have a core of sanidine and a rim of albite. Next in point of amount is the glassy base in which the felspars lie. It has a greenish colour, and has partly devitrified into a doubly refracting substance, probably a chloritoid. This glass probably has the composition of ægirine-augite. Soda-amphibole is present in minute, highly pleochroic, blue-black and green fragments, too small and ragged for exact determination.

4. Order of consolidation: the felspar had almost finished to crystallise out before the ferriferous minerals commenced to crystallise.

5. Name: Hypohyaline and orthophyric "*Anorthoclase-Arfvedsonite Trachyte*" near Orthophyre.

W.45. Loc.: Scabby Rock.

This rock resembles W.215, both in megascopic and microscopic characters. The main difference between them lies in the relative proportions of glass and arfvedsonite. In W.45 the soda-amphibole greatly exceeds the glass in amount. This rock has therefore crystallised more slowly than W.215.

W.50. Loc.: Scabby Rock.

1. Handspecimen: this rock has a grey colour; it is uneven-grained, and is readily seen to consist of heterogeneous materials.

2. Microscopic texture typical of a pyroclastic rock, tuff or breccia.

3. Composition: the main constituent is glass in peculiar boomerang-shaped and dumb-bell-shaped needles. Imbedded in the meshes of this glassy matrix lie fragments of quartz, probably derived from the surrounding sandstones, and also fragments of magnetite, felspar, and soda-amphibole crystals. The structure and nature of the constituents prove the rock to be a tuff.

4. Name: Hypohyaline Soda-trachyte Tuff.

W.39. Loc.: Timor Rock, near the "Bottle Rock."

1. Handspecimen dark greenish-grey in colour, and rather fine-grained.

2. Microscopic texture: holocrystalline, with even-grained crystals cemented with a fine, even-grained, microcrystalline base; fabric trachytic.

3. Composition: felspar forms upwards of 95 % of the mass; it consists of sanidine-anorthoclase in lath-shaped crystals, in the interstices between which the other minerals of the rock are found. The most abundant soda-amphibole present is of the type already described. There is also present in larger ragged grains a small amount of a brownish soda-amphibole, highly pleochroic in colours from a deep brownish-black to light brown, purple, and even dark green. It is commonly surrounded by a rim of blue amphibole. It is probably one of the highly titaniferous amphiboles of the cossyrite family. Frequently it occurs in optically continuous aggregates enclosing felspar in a poikilitic manner. It also seems to have affinities with katophorite. A minute quantity of interstitial ægirine is present; sometimes it is gathered round arfvedsonite crystals.

4. Order of consolidation: felspar commenced to crystallise before the other minerals. The ferriferous minerals crystallised simultaneously with the last of the felspar.

5. Name: Trachytic Soda-Trachyte. Magmatic name, Nordmakose (see Analysis W.38).

Note.—The brown pleochroic amphibole mentioned above occurs in many of the rocks of this area and the Nandewar Mountains. Occasionally it is seen to shade off into clear reddish-brown non-pleochroic ferrite, a substance which in many rocks replaces it. At first I was under the impression that the rocks containing ferrite and hæmatite were altered by weathering, but a closer examination, aided by the chemical analyses, has convinced me that the alteration is in most cases due to mineralising vapours, and took place in the period of volcanic extravasation and of the cooling of the magma. Not only do we find all gradations from arfvedsonite to ferrite (including the brown pleochroic amphiboles) in the same rocks, but the felspars are quite fresh in many rocks in which ferrite is the predominant coloured constituent, and decomposition-products are rare and the analyses do not show any notable excess of carbon dioxide or combined water above what we find in the arfvedsonite rocks (compare N.59A, an arfvedsonite rock, and N.55, a ferrite rock). The two kinds of trachyte frequently occur close together with a sharp line of demarcation between them but exposed to exactly the same weather-agencies and equally resisting to the blows of a hammer. From these facts I conclude that vapours containing HF and HCl have wholly or partly decomposed the arfvedsonite molecule subsequent to its formation, at the same time oxidising the FeO in it to Fe_2O_3, and removing the TiO_2, Na_2O and ZrO_2, redepositing them elsewhere in the rock as rutile and zircon; and a later cycle of activities restored in part these constituents, forming a rim of arfvedsonite, or perhaps more frequently the the ingress of vapours took place before the complete consolidation of the magma, and, as soon as they re-escaped, crystallisation proceeded in the normal way.

In a similar way the frequent occurrence of an envelope of ægirine round soda-hornblende, or of soda-hornblende round ægirine, may be explained. The former is probably due to the exhaustion of the mineralising vapours present in the first period of consolidation, the latter to the introduction of mineralisers after crystallisation had commenced and gone on for some time without their aid.

W.16. Loc.: base of Timor Rock.

1. Handspecimen grey in colour with bluish-black specks, giving the whole rock a bluish-grey colour.

2. Texture: like W.38, but hypocrystalline, containing a yellowish interstitial glass which gelatinises with acid and stains with malachite green. It may contain cryptocrystalline nepheline.

3. Composition: felspar similar to that in W.38 is the chief constituent. Brown amphibole and ferrite are almost wholly wanting. The blue amphibole occurs in moss-like aggregates. Ægirine is almost absent. A little limonite occurs as a decomposition-product. Round some of the felspar phenocrysts there is an isotropic white mineral which may be slightly decomposed nepheline.

4. The normal order of consolidation for these rocks was followed.

5. Name: Trachytic Soda-Trachyte. Magmatic name, Phlegrose (*cp.* Tables i. and ii.).

W.17. Loc.: Timor Rock near base. (Plate xxx., figs.1 and 2).

1. Handspecimen a bluish-grey even-grained rock like the preceding.

2. Texture hypocrystalline and even-grained, with trachytic fabric.

3. Composition: felspar forms about 90 % of the rock; it occurs in laths, most of which exhibit Carlsbad twinning, crosscracks, and other common characteristics of sanidine; but the refractive index is almost identical with that of canada balsam, so that the mineral is probably anorthoclase. There is also present a little oligoclase in laths showing albite twinning and straight extinction. Albite also occurs. The blue-green soda-amphibole is next in importance. It occurs scattered throughout the rock in minute stunted rods and elongated grains. The pleochroism colours are deep blue, greenish-blue, and greenish-yellow. Abundant inclusions of varying shapes and sizes occur. They appear to be chert fragments brought up from a depth by the lava. The soda-amphibole has aggregated round these fragments. A little interstitial quartz occurs. It was the last mineral to crystallise out. A little yellow interstitial glass is also present.

4. Order of consolidation normal.

5. Name: Trachytic Soda-Trachyte. Magmatic name, Phlegrose (see Analysis W.16).

W.114. Loc.: Paddy's Rock, Naman Range.

1. Handspecimen greenish-grey, mottled; like some of the Glass House Mountain comendites in appearance.

2. Texture: holocrystalline, even-grained, with trachytic fabric.

3. Constituents: lath-shaped anorthoclase felspars, moss-like aggregates of minute prismatic crystals of soda-hornblende, interstitial ægirine, and a little interstitial isotropic material, probably a felspathoid.

4. Name: Trachytic Soda-Trachyte.

W.109. Loc.: Gibb's Gap, near Naman. (Plate xxx., fig.4).

1. Handspecimen shining, silky, dark greenish-grey and vesicular.

2. Microscopic texture: holocrystalline, microcrystalline, and even-grained base, with trachytic fabric and flow-structure, and with occasional sanidine phenocrysts.

3. Composition: the essential constituent is felspar (soda-sanidine) of prismatic habit, sometimes tabular. Ægirine-augite and blue soda-hornblende (arfvedsonite) are present in about equal proportions. The former occurs in grains interstitially; the latter in ragged grains exhibiting the characteristic pleochroism in blue, green and yellowish-green colours. A few dark opaque grains of what is probably a titanium mineral (*e.g.*, pseudo-brookite ?) are also present.

4. Name: Vesicular Soda-Trachyte.

The rocks so far described, W.215, W.45, W.50, W.39, W.16, W.17, W.114, and W.109, exhibit close petrological and mineralogical affinity, though coming from different parts of the Warrumbungle area. They all come from plugs outstanding like monoliths, with precipitous walls; and such structures are almost universally composed of this rock-type.

W.222. Loc.: Bingy Grumble Mountain, summit. (Plate xxxi., figs.7-8).

1. Handspecimen dark grey, with white specks, and with a greasy lustre.

2. Texture holocrystalline, fine and uneven-grained, with trachytic fabric.

3. Composition: the main constituents are albite, pseudoleucite, nosean, and analcite; with ægirine, arfvedsonite, and, in smaller amount, a highly pleochroic, brownish-black amphibole in notable quantity and also in minute amount, nepheline, and augite-acmite, the last of which is colourless and has a double refraction of 0·040. The bulk of the felspar exhibits lath-shaped sections. Only Carlsbad twinning is common. Albite twinning is occasionally seen. The felspar is of two generations, there being lath-shaped phenocrysts of albite, and minute needles of a felspar

which has the habit of sanidine but is probably anorthoclase. The ægirine is highly pleochroic in colours ranging from grass-green to bluish-green. It has straight extinction, and compensates in the direction of the length of the needles. It occurs in bundles of acicular crystals, and commenced to crystallise early, being sometimes enclosed in felspar phenocrysts; and finished late, sometimes being seen enveloping arfvedsonite (*cp.* Note on p.594). The arfvedsonite occurs in characteristic moss-shaped aggregates which crystallised simultaneously with the felspar of the base. The pseudoleucite and nosean occur in the form of idiomorphic phenocrysts giving square, hexagonal, and polygonal sections, but rarely showing cleavage. Some of the crystals are clear, but most are dusty from an abundance of inclusions. In addition there are irregular patches of an isotropic mineral which is sometimes clear and sometimes yellowish from zeolitic decomposition-products. This mineral is frequently seen in the intervals between needles of felspar arranged in radiating, pseudospherulitic manner. Probably it is analcite. The decomposition-products are kaolin, zeolites, and ferrite.

4. Order of consolidation :

i. Phenocrysts of Albite
ii. Ægirine
iii. Nosean
iv. Anorthoclase
v. Arfvedsonite
vi. Katophorite (?)
vii. Augite Acmite
viii. Analcite (?)

5. Name : Trachytic Nosean-Analcite-Phonolite. Magmatic name, Nordmarkose (see Analysis W.222).

6. Chemical Notes : all the patches referred to the felspathoid group of minerals gelatinise with acids and take stains strongly.

W.220. Loc.: Mount Bingy Grumble.

1. Handspecimen dark brownish with greasy lustre; porphyritic in phaneric phenocrysts.

2. Texture: hyalopilitic fabric; uneven in grain.

3. Composition: the constituents are acicular felspars (albite and anorthoclase), ragged grains of arfvedsonite, and an isotropic base which does not gelatinise and stain. A little magnetite is present, and also decomposition-products such as kaolin, zeolites and brown iron ores.

4. Name: Hyalopilitic Trachyte.

W.140. Loc.: Berum Buckle. (Plate xxxi., figs. 9-10).

1. Handspecimen: a dark grey mottled rock, with large phaneric phenocrysts of tabular felspar.

2. Texture: holocrystalline, with porphyritic phenocrysts in a very fine, even-grained trachytic base.

3. Composition: the felspar is of two generations, consisting of phenocrysts of sanidine (or anorthoclase?) and the anorthoclase of the base in minute needles. The usual aggregates of blue hornblende abound, as well as the same mineral in stunted rod-shaped grains. Almost isotropic phenocrysts of regular six-sided, octangular, and four-sided outlines, and of a yellowish colour are present in abundance. They show an anomalous double refraction in the centre, which is partly due to an abundance of inclusions. These phenocrysts consist of altered leucite (pseudoleucite) and nosean. The inclusions in them are, in part at least, felspar. The felspar phenocrysts also contain throughout inclusions of isotropic material, apparently leucite, and of cancrinite, whilst in the outer zone arfvedsonite is occasionally included. The soda-amphibole also tends to crowd round the isotropic phenocrysts. Ægirine-augite occurs interstitially. Accessories are zircon, rutile, etc., as inclusions.

4. Order of consolidation:

1. Zircon, Rutile, Apatite
2. Leucite (now pseudoleucite)
3. Sanidine phenocrysts
4. Nosean
5. Blue Amphibole
6. Ægirine
7. Anorthoclase base

5. Name: Trachytic Nosean-Arfvedsonite-Leucitophyre. Magmatic name, Phlegrose.

6. Chemical Note: this rock gelatinises strongly with acid and takes stains. The absence of chlorine shows that sodalite is not present, and the low percentage of SO_3 shows that the almost isotropic material which is a very abundant constituent (more than 10% of the bulk) cannot be wholly nosean. The low CO_2 and H_2O percentages of the rock, as well as the regular outlines of the isotropic mineral, show that this cannot be a zeolite (amygdaloidal fillings). The investigation therefore indicates that it it must be pseudoleucite.

W.141. Loc.: Tenandra Gap between Caraghnan and Mount Berum Buckle.

1. Handspecimen like W.140.

2. Texture like W.140.

3. Composition: the constituents are the same as in W.140, with these differences:—the felspathoid minerals are less abundant, ægirine-augite is more abundant, exceeding soda-hornblende in amount; and the latter mineral is a brownish variety allied rather to barkevicite and cossyrite (?) than to arfvedsonite, and is scattered about in minute grains and rods. The isotropic minerals gelatinise with acids and take stains.

4. Name: Trachytic Nosean Soda-amphibole Leucitophyre.

W.138. Loc.: A ridge N.E. of Mount Berum Buckle.

1. Handspecimen a mottled, uneven-grained yet fine-grained greenish-grey rock.

2. Texture: fabric trachytic, holocrystalline, porphyritic in felspathoid.

3. Composition: the felspar consists essentially of anorthoclase in laths. Ægirine, arfvedsonite and brownish soda-amphibole are represented. A few cubes of magnetite are present.

4. Name: Trachytic Nosean-Pseudoleucite Trachyte.

Note: the last four rocks here described, viz., W.222, W.140, W.141 and W.138, are closely allied, and belong to the group of the phonolites. In the Warrumbungles this rock-type (typified in W.140) forms a connecting link between the light arfvedsonite trachytes like W.116, and the dark ægirine-trachytes (and phonolitic trachy-andesites) like W.1, W.22, etc. In both physical appearance and volcanic succession they are intermediate between these two groups.

W.124. Loc.: Needle Mountain.

1. Handspecimen of a greenish colour and shining lustre. It is porphyritic in shining tabular felspars.

2. Texture holocrystalline, uneven-grained, with phaneric felspar phenocrysts, and trachytic fabric of the base.

3. Composition : the constituents, in order of decreasing abundance, are felspar, ægirine-augite, ferrite, magnetite, and blue amphibole. Only felspar and ægirine-augite are represented in notable amount. The felspar phenocrysts are tabular, and show Carlsbad twinning; from their cleavage angle, low refractive index (less than canada balsam), and extinction angles they are seen to be composed of albite. They include ægirine grains. The felspar needles composing the base are probably also albite, but may be partly sanidine or anorthoclase. The ægirine-augite occurs in idiomorphic twinned phenocrysts (twinning plane parallel to a (100), with moderate pleochroism). The extinction angles on the cleavage in sections showing but one cleavage are moderately high. It is therefore true ægirine-augite, and occurs abundantly in minute idiomorphic grains. Magnetite and soda-amphibole occur only in very minute proportions.

4. Order of consolidation :

1. Magnetite ———
2. Ægirine ——————
3. Albite (phenocrysts) ————————
4. Felspar of base ——————

5. Name : Trachytic Ægirine Soda-Trachyte.

Note : this rock is interesting as showing that an absence of mineralising vapours in the soda-trachyte magma leads to the crystallising out of the ferric constituents as magnetite, ægirine and ferrite (from the excess of Fe_2O_3), and these minerals under such conditions commence to form before the felspar.

W.113. Loc.: Tooraweanah Mountains, summit.

1. Handspecimen dark greenish-grey in colour, almost aphanitic.

2. Texture holocrystalline, even- and fine-grained with pilotaxitic fabric.

3. Constituents (in order of decreasing abundance): felspar occurs in lath-shaped sections, and appears to belong to the species anorthoclase. The ægirine-augite is a somewhat strongly pleochroic variety changing from light leek-green to dark green and greenish-yellow. It occurs in needles and prismatic grains with frayed ends. Biotite in irregular fragments is present in the same proportion as ægirine-augite. As accessories we find magnetite and ferriferous decomposition-products.

4. Name: Pilotaxitic Biotite Ægirine-Trachyte.

5. Note: biotite occurs in varying, usually very minute proportions, in most of the dark-coloured trachytes in which the main femic constituent is ægirine-augite. These trachytes are closely related to and graduate into andesites.

W.117. Loc.: Naman Ledges opposite Black Mountain on Uargon Creek.

1. Handspecimen dark greenish in colour, with even fracture, silky lustre, and aphanitic grain-size.

2. Texture as in W.113.

3. In composition it differs from W.113 in that biotite is exceedingly rare; and it contains a few irregular masses of dolomite, which probably represent infilled vesicles.

Name: Pilotaxitic Ægirine Trachy-Andesite.

W.9. Loc.: Timor Ledges, Warrumbungle Range, one mile north of Timor Rock. (Plate xxx., fig.5).

1. A dark aphanitic, silky rock, with even fracture.

2. In texture like W.117.

3. Composition as in W.117, but there is no dolomite, and a little chlorite is present. The chlorite probably represents altered ægirite or glass, and occurs in almost isotropic patches with a fibrous structure.

4. Name: Pilotaxitic Ægirine Trachy-Andesite. Magmatic name, Monzonose (see Analysis W.1).

Note: this specimen is the same as W.1, which was analysed. The analysis of W.1 represents the composition of most of the great flows of trachy-andesite lava and phonolitic trachyte which followed the outbursts of true trachyte and phonolite. In these flows the iron, lime, and magnesia are higher, and the silica lower than in the trachytes. However, their high percentages of alkali and Al_2O_3 show their definite relationship to the other rocks. The trachy-andesites were tested for felspathoids with acid and staining reagents. Rocks of similar appearance from different parts of the Warrumbungles were sectioned and tested. Most resisted the reagents, but a few stained slightly in the ground-mass, and sometimes small nephilinitoid crystals took the stain. It appears therefore that most of these rocks are free from felspathoid mineral, but some contain a little interstitial nepheline. On account of their close resemblance to one another in physical, mineralogical and chemical characters and their close field-relationship, I have classed these rocks together as trachy-andesites and phonolitic trachytes.

W.127. Loc.: ridge between Berum Buckle and Belar Creek, about one mile N.E. of Berum Buckle.

1. Handspecimen not unlike Gib Syenite. It abounds in vesicles (miarolitic structure).

2. Texture holocrystalline, uneven-grained, porphyritic with trachytic fabric in the groundmass.

3. Composition: the essential constituent is orthoclase of prismatic and acicular habit (giving lath-shaped sections). The other minerals present are phenocrysts of magnetite, needles of ægirine, irregular grains of soda-amphibole and ferrite with iron-bearing decomposition-products.

4. Name: Porphyritic Soda-Trachyte.

W.135. Loc.: same as W.127. This rock is similar in every respect to the preceding.

W.121. Loc.: Mount Caraghnan, summit.

1. Handspecimen of a dark colour.

2. Texture holocrystalline, fine- and even-grained, with pilotaxitic fabric approaching panidiomorphic-granular.

3. Composition : it consists of felspar laths, and ægirine-augite in needles and stunted prisms.

4. Name : Ægirine Trachyte.

W.132. Loc.: Damnation Gully, below and north of Mount Caraghnan.

1. Handspecimen of a brick-red colour; grain-size uneven; fracture rough; lustre silky.

2. Texture as in W.127 and W.135.

3. Composition : the same minerals occur as in W.127 and and W.135, with which rocks it has close affinities. It is porphyritic in tabular and lath-shaped felspars and in magnetite. The felspar phenocrysts are albite. The other minerals represented are bluish-green highly pleochroic soda-hornblende (arfvedsonite?), hæmatite, the felspar of the base and ferric decomposition-products.

4. The hæmatite is an original constituent and crystallised immediately after the magnetite.

5. Name : Porphyritic Magnetite Soda-Trachyte.

W.125 from Damnation Gully is similar to W.132 except in that most of the phenocrysts are composed of anorthoclase showing Carlsbad twinning.

W.142. Loc.: south slope of Mount Caraghnan.

1. Handspecimen reddish when weathered, greenish-grey when fresh; lusture silky, fracture rough.

2. Texture : holocrystalline, porphyritic hence uneven-grained, with a fine-grained base composed essentially of felspar laths.

3. Composition : the felspar phenocrysts appear to be partly anorthoclase, partly albite. The felspar of the ground-mass is sanidine or anorthoclase. Biotite occurs abundantly in frag-

mentary flakes and is evidently foreign to the magma, having been snatched up in the upward passage of the lava from the strata penetrated. A little arfvedsonite, some grains of ægirine, and a few grains of magnetite are also present.

4. Name: Porphyritic Albite-Biotite Soda-Trachyte.

W.22. Loc.: Nandi Mountain, Coonabarabran. (Plate xxx., fig.6).

1. Handspecimen dark in colour, porphyritic and rather more coarse-grained than those previously described.

2. Texture: holocrystalline, fairly even-grained but for the phenocrysts: grain-size averaging less than 1 mm., hence fine; fabric panidiomorphic-granular.

3. Composition: the essential constituent is felspar of prismatic habit, giving square, rectangular, and lath-shaped sections. Twinning is on the Carlsbad law. The crystals are zoned, the interior portion being full of dark inclusions of magnetite and chlorite, the outer portions being usually clear. The felspar has usually slight extinction, but occasionally it extinguishes at low angles up to 10°. The refractive index is lower than that of canada balsam. It appears to be essentially orthoclase and anorthoclase. The mineral next in order of decreasing abundance is olivine, which occurs in partially resorbed phenocrysts showing incipient decomposition to serpentine. Ægirine-augite occurs both included in felspar and interstitially. It has the acicular habit. Magnetite occurs, primary in idiomorphic cubes as inclusions in felspar, and also interstitially in the ground-mass. Secondary magnetite in mossy aggregates is also present. Serpentine and chlorite occur sparingly as decomposition-products.

4. Order of consolidation: the felspar is of two generations, the portion abounding in inclusions having probably formed in a deep-seated magmatic reservoir. Crystallisation commenced with the olivine which is devoid of inclusions.

We therefore have the following order :—

Olivine ————
Magnetite ——————
Felspar, 1st gen. ————
Ægirine ——————
Felspar, 2nd gen. ——————

5. Name : Panidiomorphic Olivine-Trachy-Andesite (*Keratophyre* of Rosenbusch).

Note : another slide of the same specimen showed, in addition to the minerals already mentioned, an interesting brown mineral highly pleochroic in colours from deep reddish brown to yellowish-brown. It shows no trace of cleavage, but is highly corroded and full of magnetite inclusions, some of which are undoubtedly primary and most probably secondary. Fragments of it also occur adhering to the mossy magnetite aggregates. Both are probably secondary. The shape of the crystals of this brown mineral suggests hornblende or hypersthene, and the inclusions are arranged as in hypersthene. The mineral is probably *pseudobrookite* secondary after titaniferous rhombic pyroxene or hornblende.

Chemical Analysis : Specimen W.22 is in physical appearance very like W.1 (trachy-andesite), and in chemical composition these rocks are also very close. The Nandi rock is, however, richer in ferric oxide and titanic acid. The excess of the latter has combined with Fe_2O_3, and probably Na_2O and SiO_2, to give a femic mineral subsequently altered to pseudobrookite (?), leaving an excess of FeO free to combine with MgO to form olivine.

Magmatic name of W.22, Monzonose (*cp.* Tables i. and ii.).

W.32. Loc.: The Forked Mountain, near Coonabarabran.

This rock resembles W.22 both macroscopically and microscopically. However, it contains some beautiful ægirine-augite phenocrysts and fine plates of red micaceous hæmatite which is an original mineral. Acicular crystals of apatite are present.

Name : Hypidiomorphic-granular Olivine Hæmatite Trachy-Andesite or Keratophyre (Rosenbusch).

W.30. Loc.: The Forked Mountain.

In this rock the ægirine-augite phenocrysts are still more plentiful, and hæmatite less so than in W.32.

Name: Ægirine-Olivine Trachy-Andesite.

The Nandi, Forked Mountain, and other rocks from the buttes around Coonabarabran must be ranked as trachyandesites on account of their peculiar mineralogical composition. They are intermediate between the trachyandesites (and phonolitic trachytes) of Timor Ledges, Naman Ledges, etc., and the sodalite or analcite basalts of Tonduron (The Spire) and Wombalong (Mount Exmouth). They are apparently the volcanic equivalents of an essexite magma. Variations in the relative proportions of ægirine, hæmatite, olivine, and pseudobrookite (?) seem to have been controlled essentially by variations in the titanium percentage in different portions (*cp.* Analyses W.1, W.22; and petrological descriptions W.117, W.9, W.22, W.32, W.30).

Minerals of Trachyandesites, Trachydolerites and Sodalite Basalts.

The minerals contained in common by these rocks are:—

(a) Plagioclase Felspar. This mineral occurs in phenocrysts which show Carlsbad, Albite, and Pericline twinning. Its extinction angle in symmetrical sections varies from 10° to 25°. Presumably the varieties albite, oligoclase, andesite, and labradorite are all present. In the ground-mass the felspar has the form of needles, and fine laths whose refractive index is lower than that of canada balsam and whose extinction angles are very low. It is probably albite or anorthoclase.

(b) Orthoclase Felspar occurs both as fragmentary phenocrysts and as fine laths (sanidine) in the base. It is probably soda-bearing, and often graduates into albite or anorthoclase.

(c) The olivine is a clear colourless variety which occurs as highly corroded phenocrysts with serpentinous cracks. It is the chief mineral found included in the felspar phenocrysts.

(d) Several varieties of augite occur. The chief is a light brownish or copper-coloured, titaniferous, slightly pleochroic diallage. This kind is of two generations, the first occasionally forming phenocrysts which may include olivine. The phenocrysts are quite allotriomorphic, and often bound together in such a way as to indicate that the rock is derived from the refusion of a coarsely crystalline gabbro or theralite. The second generation occurs in minute idiomorphic grains in the base, and sometimes ophitically intergrown with felspar.

Darker brown titaniferous augite and greenish varieties allied to ægirine occur in some of the rocks.

(e) Apatite is a common constituent in minute quantities, and occurs in the form of long needles often included in the felspar and augite phenocrysts.

(f) Magnetite in idiomorphic cubes and ilmenite in hexagonal plates are both very common.

(g) Sodalite or analcite with very low refractive index and completely isotropic is a common constituent. It occurs in perfectly clear but very irregular patches in the interstices between the other minerals. It stains strongly.

As inclusions, in the albite phenocrysts particularly, we find olivine, apatite, magnetite, augite, ægirite, and occasionally biotite.

An interesting point is that in these rocks the felspar phenocrysts are always corroded less than those of augite and olivine. It appears therefore that the basic nature of these rocks is due to the remelting and absorption of a gabbro, theralite or essexite by an acid alkaline magma. An acid magma would exercise greater corrosive (chemical) influence on the basic minerals of the absorbed rock than on the acid ones. The felspars would only be slightly corroded, and would rather tend to grow as the magma cooled. We should therefore expect, and actually do find, zoning common in the felspars of these basic rocks.

W.67. Loc.: Tonduron (The Spire), head of Spire Creek. (Plate xxxi., figs.5-6).

1. Handspecimen a dark bluish-black rock with splintery fracture and oily lustre.

2. Texture: holocrystalline, very uneven-grained, porphyritic with large phaneric phenocrysts, and with pilotaxitic base.

3. Composition: the plagioclase consists of phenocrysts of acid labradorite idiomorphic in outline and idiomorphic albite phenocrysts with corroded edges and numerous inclusions. Amongst the inclusions the most abundant are of augite, magnetite and olivine, but muscovite and quartz fragments also occur. The latter are evidently of extraneous origin. The second generation of felspar consists of prismatic needles of clear albite and anorthoclase. Many of the phenocrysts show Schiller structure, and zoning is very frequent, the outer portions of a crystal being the more acid. The augite is of two generations, the first being diallagic. The olivine is also of two generations. The most abundant iron ore is magnetite, which occurs chiefly in the base. Apatite is also present. A mineral of the sodalite group occurs interstitially. Less important are the following:—orthoclase phenocrysts in rare fragments; quartz fragments included in the felspar phenocrysts; talc included in labradorite, especially in the crystals showing Schiller structure, and rare flakes of muscovite which may be either primary inclusions or secondary developed by alteration. All these minerals are xenocrysts.

4. Order of consolidation:

1. Olivine
2. Felspar phenocrysts
3. Diallage
4. Apatite
5. Magnetite
6. Augite (2nd generation)
7. Albite (2nd gen. felspar)
8. Isotropic sodalite or analcite (interstitial)

Remarks: the augite of the first generation is a titaniferous (reddish) diallage, whereas that of the second generation is a light green or colourless diopside. Round the corroded felspar phenocrysts of the first generation there is frequently a deposit of laths of acid felspar arranged parallel to the original crystal. This deposit frequently encloses magnetite grains.

As shown in Plate xxxi., fig.5, this rock contains aggregates of coarse crystals of olivine, felspar, and pyroxene, not unlike inclusions of partly resorbed olivine gabbro. From this characteristic, considered in conjunction with the occurrence of the felspar of talc and muscovite (sericite ?) and of Schiller structure, and with the presence of diallagic augite and an alkaline base, the rock appears to have been formed by the crushing and partial refusion of an olivine gabbro, and the blending of the mass thus formed with an alkaline magma.

5. Name: Pilotaxitic Orthoclase (and Sodalite ?) Basalt, allied to Trachydolerite. Magmatic name, Akerose (see Tables i. & ii.).

W.201. Loc.: Mt. Exmouth, summit.

1. Handspecimen a dark bluish-black porphyritic rock with greasy lustre and splintery fracture.

2. Texture: almost holocrystalline, with very variable grain-size. The base is very fine-grained (microcrystalline) and has a hyalopilitic fabric in places, trachytic in others.

3. Constituents (in order of decreasing amount): felspar occurs in idiomorphic, only slightly corroded phenocrysts of medium labradorite, and in fine microscopic needles varying from albite to labradorite. Olivine in corroded phenocrysts. Augite rarely as very corroded, rounded phenocrysts, but abundant in minute grains throughout the base; it is a titaniferous variety. Magnetite in idiomorphic grains. A little glass is also present, as well as accessories comprising serpentine (decomposition-product), apatite and sodalite (or allied isotropic mineral).

4. Name: Porphyritic Hyalopilitic Olivine Basalt.

W.85. Loc.: Uargon Tableland, south of Black Mountain. (Plate xxxii., fig.1).

1. Handspecimen like the preceding.

2. Texture like W.67 with pilotaxitic-ophitic fabric.

3. Composition: the phenocrysts comprise felspar varying from acid labradorite to andesine; corroded olivine; augite so inter-

penetrated with felspar as to appear broken up into grains yet optically continuous over small areas. The base is microcrystalline and consists of titaniferous augite in prismatic grains; acid plagioclase (oligoclase and albite); an isotropic mineral with very low refractive index occurring in irregular patches, probably sodalite; and idiomorphic magnetite grains. The felspar phenocrysts contain inclusions of an isotropic colourless mineral (analcite from decomposition).

Name: Porphyritic Ophitic Olivine-Sodalite Basalt.

W.207. Loc.: summit of Terra-Terra.

1. Handspecimen somewhat decomposed, highly porphyritic in plagioclase (albite).

2. Texture: the base is very fine, microcrystalline, with hyalopilitic fabric.

3. Constituents (in order of decreasing amount): (a) felspar, (b) magnetite, (c) ferrite and hæmatite, (d) sodalite (or analcite), (f) glass, (g) nepheline. The felspar is essentially albite, and occurs in the base in minute laths. The red iron ore is derived from the decomposition of magnetite, though some of the hæmatite may be original. Olivine and augite are absent. The composition being essentially made up of albite and magnetite, this rock is necessarily very alkaline. I have examined specimens of a rock of the same composition collected by my brother, Mr. Thor Jensen, L.S., at Coorombin Creek, Q., near the McPherson Range.

4. Name: Nepheline-Sodalite Tephrite.

W.58. Loc.: one mile east of Gowang Station. (Plate xxxii., figs. 2-3).

1. Handspecimen coarsely porphyritic with aphanitic base and splintery fracture.

2. Texture: holocrystalline with phenocrysts exceeding 5 mm. in diameter, and a very fine microcrystalline base with pilotaxitic fabric.

3. The constituents comprise felspar, a honey-yellow mineral which seems to be meliphanite, magnetite, olivine, fine-grained augite and apatite. The felspar phenocrysts range in basicity from acid labradorite to albite. Many are zoned, the outer zone being of a very acid character. The lath-shaped felspars of the base appear to be anorthoclase. A very curious phenomenon may be observed in some parts of the base. Viewed in plane polarised light without the analyser, it looks like a pilotaxitic mass of hypidiomorphic crystallites of different minerals. Yet as soon as the analyser is put on, certain patches appear to contain a base which is optically continuous over the whole area, and these patches have definite crystalline outlines. They behave, in fact, like phenocrysts of very acid felspar (apparently anorthoclase) embracing crystallites of lime-soda felspar, meliphanite, magnetite, augite and olivine. Some of the basic felspar phenocrysts merge imperceptibly into the ground-mass. Many are deeply corroded, but do not merge into the ground-mass. The yellow mineral, provisionally termed meliphanite, is quite allotrimorphic. It is rather pleochroic from yellow to greenish-yellow. Some thin flakes are light green in colour. It crystallised last, for it commonly envelops the other minerals and occurs interstitially. The double refraction is strong and the refractive index moderate. Apatite occurs in allotriomorphic fragments. The magnetite is idiomorphic. The pyroxene consists of minute grains and laths of colourless to greenish diopside. Chlorite occurs secondary after diopside. In some sections a bluish isotropic mineral, probably haüyne, occurs interstitially.

4. Order of consolidation :

1. Felspar Phenocrysts ————
2. Olivine ——
3. Magnetite ——
4. Felspar ——
5. Meliphanite ——

5. Name : Pilotaxitic Meliphanite-Olivine-Basalt.

Remarks.—The curious patches of optically continuous felspar noted above and the various stages of absorption exhibited by the felspar of the first generation are matters which suggest that this rock originated by the refusion of a previously existing gabbro. The fused mass then received an addition of alkaline magmatic waters and a little alkaline lava. On the magma reaching the surface many of the phenocrysts which had survived the upward passage were now recrystallised. The recrystallisation must have taken place after the lava came to rest, otherwise the outlines of the crystals would have been lost. A kind of hydato-igneous fusion must have taken place, otherwise we cannot imagine how the magnetite was introduced, unless these crystals were rich in inclusions to begin with.

W.40. Loc.: Billy King's Creek, 2½-3 miles south of Coonabarabran. The rock forms a lava-flow.

1. Handspecimen black in colour, consisting of a dark aphanitic base containing a few felspar phenocrysts.

2. Texture : the base is very fine-grained, and has a trachytic fabric.

3. Constituents : the felspar phenocrysts consist of albite; the felspar of the base is mainly albite, but a little anorthoclase appears to be present as well. A couple of perfectly rounded phenocrysts of andesine also occur. The next constituent in order of abundance is a black dusty mineral, usually opaque, but occasionally showing slight translucency with a bluish tint. Sometimes this mineral is seen in four-sided, five-sided, or six-sided grains, but more often it is quite allotriomorphic, and occasionally the dust occurs in groupings similar to the ophitic groups of riebeckite in the trachytes. Most of it has a dull lustre and is probably a variety of emery or corundum. A few of the cubical grains consist of magnetite. It is possible that a black, opaque garnet mineral may be present as well. The felspar forms roughly 55-60 % of the bulk of the rock, the black opaque minerals 10-15 %. Next in order of abundance we have a yellow or brownish-yellow mineral in acicular prisms and

columnar grains. It shows a strong pleochroism giving reddish or brownish-yellow, wine-yellow and very pale yellow. Irregular cracks in a direction transverse to the length of the prisms sometimes occur. A cleavage, and occasionally twinning, may be noticed running in the direction of the length of the crystals. The extinction angle varies from 0° to 20°. Double refraction is strong. From these characters, the mineral, which forms about 10 % of the rock, appears to be laavenite. Next in order of abundance we have minute prisms, grains and lozenge-shaped microlites, clear colourless sphene with characteristic high refractive index and double refraction. A light greenish to colourless diopside also occurs in grains. Melilite occurs in patches and is moulded on the felspar enveloping it in an ophitic manner. It has the characteristic peg-structure. Finally we have an isotropic colourless interstitial substance which gelatinises with acid; it probably consists of leucite or analcite.

4. Order of consolidation :

1. Sphene ————
2. Felspar (2nd gen.) ————————————
3. Corundum (?) ————
4. Laavenite (?) ————
5. Melilite ————
6. Isotropic base ————

A little primary hæmatite is present, and crystallised out early. The felspar of the first generation was highly corroded by the magma just before the period of crystallisation. A ferromagnesian mineral (either an amphibole or pyroxene) was also originally present but was completely resorbed, and one can only trace its former presence by the existence of patches of dusty corundum and magnetite and isotropic mineral, which have the outline of hornblende phenocrysts. The orginal mineral has been completely pseudomorphosed.

The chemical composition of the rock is so extraordinary that one can only account for the amount of Fe_2O_3 by assuming that the black mineral is, in part at least, garnet. In this way the spare SiO_2 (quartz of the norm) would also be used up and conditions for the production of leucite or analcite in the base would be brought about.

4. Name: Corundum (?) Basalt (with sphene, melilite and laavenite). Magmatic name, Monzonose.

Note: the occurrence of blue corundum in rare grains in this rock is confirmative of the Rev. J. M. Curran's theory as to the origin of our sapphires.

The rock (W.40) has many points in common with W.58, but contains no olivine.

W.64. Loc.: Tableland south of Belar Creek.

1. Handspecimen dark grey rock with rough fracture; looks like andesitic basalt.

2. Texture: holocrystalline, uneven-grained, with ophitic fabric.

3. Composition: labradorite felspar in laths, but not as phenocrysts. Only one generation is developed. Brownish, titaniferous, somewhat pleochroic augite, occasionally pierced by felspar laths. Colourless olivine in corroded phenocrysts. Magnetite in idiomorphic grains; ægirine in needles lying interstitially between felspar laths; and orthoclase also interstitial. An isotropic mineral of the noselite group, or perhaps leucite, also occurs interstitially.

4. The occurrence of ægirine and orthoclase in this rock justifies its classification as a trachy-dolerite.

5. Name: Ophitic Olivine Trachy-Dolerite.

Other specimens from other parts of the same tableland were similar macroscopically and microscopically. This rock covers a great area.

M.6. Loc.: 34-mile peg, Gunnedah-Coonabarabran Road.

This rock is a holocrystalline, fine-grained, ophitic dolerite with porphyritic olivines. It is composed of labradorite, titaniferous augite, and olivine, with magnetite and apatite as abundant minor constituents.

Name : Olivine-Dolerite.

This rock is calcic and has no relation with the alkaline series.

M.1. Loc.: Hilltop, Black Jack Coal Mine, Gunnedah.

This is a holocrystalline, medium-grained dolerite porphyritic in olivine and titaniferous augite. It contains labradorite (lath-shaped), idiomorphic phenocrysts of purplish augite, corroded olivine phenocrysts, idiomorphic grains and phenocrysts of magnetite, and interstitially analcite Apatite occurs as an accessory. The isotropic mineral darkens on heating and gelatinises with acid. It is therefore analcite, but appears to be of secondary origin in part at least.

Name : Olivine-Analcite-Dolerite.

The microscopic investigation of the rocks of the Warrumbungle Mountains brings out the following points, namely :—(1) the existence in the district of a complete series of alkaline rocks ranging from acidic comendites to basic sodalite-analcite basalts; (2) the gradation of these rocks into one another; and (3) that in the volcanic period older basic rocks were remelted at depths in various places, and, after being mixed with more acid alkaline magma, rose to the surface.

The alkaline rocks include—

(1) Riebeckite Comendites } *cp.* Anal.
(2) Pantellarites }
(3) Arfvedsonite Trachyte.
(4) Nosean-Leucite Trachytes and Phonolites.
(5) Ægirine Anorthoclase Trachydolerites and Trachytes.
(6) Albite Magnetite Basalt without olivine or augite.
(7) Sodalite and Analcite Basalts, sometimes with melilite and meliphanite (?).
(8) Garnet and Corundum-bearing Basalts, with laavenite and melilite.

A comparison of the chemical analyses with one another and with the mineralogical characters is very instructive.

TABLE I.—CHEMICAL ANALYSES OF ROCKS FROM THE WARRUMBUNGLE MOUNTAINS.

	W.67. Orthoclase-Basalt. Loc.: Tonduron or Spire.		W.40. Corundum-Basalt. Loc.: Billy King's Creek, near Coonabarabran.		W.1. Trachy-andesite. Loc.: Timor Ledges		W. 22. Trachy-andesite. Loc.: Forked Mtn.		W.222. Nosean Phonolite. Loc.: Bingy Grumble Mountain.		W.140. Pseudoleucite Nosean Phonolite Loc.: Berum Buckle Mountain.		W.16. Arfvedsonite Trachyte. Loc.: Timor Rock.	
	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.
SiO_2	51·88	0·865	48·27	0·805	58·95	0·983	58·32	0·972	60·32	1·005	62·42	1·040	65·90	1·098
Al_2O_3	14·20	0·139	18·02	0·176	17·04	0·167	18·04	0·176	18·32	0·179	17·69	0·174	16·74	0·164
Fe_2O_3 ...	3·72	0·023	12·06	0·076	2·80	0·018	3·27	0·021	3·55	0·022	2·72	0·017	1·72	0·011
FeO	6·87	0·096	0·90	0·013	4·66	0·065	4·28	0·060	1·96	0·026	2·19	0·031	1·99	0·028
MnO	0·02	0·001	0·03	0·001	0·05	0·001	0·06	0·001	0·03		0·08		0·06	
NiO	0·04		0·04		0·01		trace		0·05	0·001	trace	0·001	0·01	0·001
CoO	abs.	—	trace	—	abs.	—	abs.	—	trace		abs.		trace	
MgO	4·62	0·115	1·17	0·029	0·57	0·014	0·58	0·014	0·01	0·001	0·20	0·005	0·06	0·002
CaO	6·36	0·114	6·06	0·109	2·49	0·045	2·52	0·045	1·12	0·020	1·53	0·027	0·09	0·002
Na_2O	3·93	0·063	3·73	0·060	4·51	0·073	4·52	0·073	7·01	0·113	5·93	0·096	6·35	0·103
K_2O	3·27	0·035	3·33	0·035	6·39	0·068	6·21	0·066	6·25	0·067	6·29	0·067	5·77	0·062
H_2O (100°C –)	0·58	0·117	0·85	0·078	0·59	0·106	0·35	0·072	0·35	0·094	0·24	0·050	0·27	0·039
H_2O (100°C +)	1·44		0·52		1·28		0·95		1·31		0·69		0·43	
CO_2	0·29	0·007	0·30	0·007	0·06	0·001	—	—	trace		abs.		abs.	
TiO_2	3·54	0·044	4·87	0·061	0·76	0·009	1·25	0·015	0·25	0·003	0·35	0·005	0·25	0·003
ZrO_2	—	—	0·04	—	0·17	0·001	—	—	0·38	0·003	0·20	0·002	0·29	0·002
P_2O_5	trace	—	trace	—	abs.	—	pre.n.d.		abs.		abs.		abs.	
Cl	trace	—	trace	—	trace	—	—		abs.		—		trace	
F	—	—	0·11	0·005	abs.	—	—		—		—		0·16	0·008
SO_3	0·04	—	abs.	—	trace	—	—		0·11	0·001	0·05	0·001	abs.	
S	—*	—	abs.	—	abs.	—	—*		abs.*		abs.*		abs.*	
BaO	abs.		abs.		abs.		abs.		abs.†		abs.†		abs.†	
SrO	abs.		abs.		abs.		abs.		abs.†		abs.†		abs.†	
Li_2O	—		abs.		abs.		abs.		abs.†		abs.†		abs.†	
Sum... ..	100·80		100·30		100·33		100·35		101·02		100·58		100·09	

* No Pyrites. † Spectroscopic test only.

TABLE I.—CHEMICAL ANALYSES OF ROCKS FROM THE WARRUMBUNGLE MOUNTAINS *(continued)*.

	W.38. Arfvedsonite-Ægirine Trachyte. Loc.: Timor Rock.		W.127. Porphyritic Soda Trachyte. Loc.: N.E. of Berum Buckle.		A. Trachyte. Loc.: Mt. Flinders, nr. Ipswich, Queensland (Analyst, H. I. Jensen).		B. Trachyte. Loc.: Parish of Dungarry, near Dubbo, N.S.W. (Analyst, B. White, Rec. Geol. Surv. N.S.W.)		C. Trachyte. Loc: The Canoblas, nr. Orange, N.S.W. (Analyst, B. White, Rec. Geol. Surv. N.S W.)		D. Trachyte. Loc.: Wantialable Ck., Warrumbungle Mts. (Analyst, J. C. H. Mingaye, Rec Geol. Surv. N.S W. iv. p. 116, 1895).		E. Ægirine Trachyte. Loc.: Mount Jellore, Mittagong. (Analyst, D Mawson, Journ. Roy. Soc., N.S.W., xxxvii.).	
	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.
SiO_2	63·82	1·064	60·73	1·012	60·58	1·010	67·68	1·128	72·06	1·201	74·12	1·235	66·68	1·111
Al_2O_3	17·85	0·175	18·16	0·178	18·06	0·177	13·99	0·137	13·86	0·136	12·39	0·122	14·63	0·143
Fe_2O_3	2·75	0·017	4·63	0·029	3·05	0·019	3·20	0·020	1·90	0·012	0·31	0 002	2·18	0·014
FeO	1·67	0·024	0·20	0·003	1·38	0·019	1·98	0·028	1·71	0·024	0·21	0·003	2·31	0·032
MnO	0·04		0·10		0·04		0·02		0·07		trace		0·49	0·007
NiO	abs.	} —	trace	} 0·001	0·07	} 0·002	abs.	—	abs.	} 0·001	—		—	
CoO	abs.		trace		trace		abs.		abs.		—		—	
MgO	0·06	0·002	0·31	0·008	0·23	0·006	0·34	0·009	0·19	0·005	0·42	0·010	0·30	0·007
CaO	0 59	0·011	0·10	0·002	1·74	0·030	0·84	0·014	0·18	0·004	0·30	0·005	1·88	0·034
Na_2O	7·13	0·115	4·88	0·079	5·01	0·081	5·30	0·085	5·84	0·094	3·22	0·052	6·12	0·098
K_2O	5·51	0·059	6·21	0·066	6·87	0·073	4·87	0·052	3·69	0·039	5·07	0·054	4·02	0·043
H_2O (100°C −)	0·66	} 0·050	0·72		0·99	} 0·106	0·65	} 0·094	0·21	} 0·028	2·22	} 0·239	0·38	} 0·067
H_2O (100°C +)	0·20		1·33	} 0·117	0·90		1·05		0·33		2·10		0·83	
CO_2	abs.		trace		—		0·02	—	0·03	0·001	—	—	0·05	0·001
TiO_2	0·25	0·003	0·60	0·008	0·83	0·010	0·20	0·003	0·12	0·001	—		0·20	0·003
ZrO_2	—		—		—		abs.		abs.		—		trace	
P_2O_5	abs.		abs.		—		0·04		0·06		—		0·28	0·002
Cl	trace		0·03		—		trace		trace		—		0·03	
F	—		—		—		—		—		—		—	
SO_3	—		—		trace		abs.		abs.		trace		trace	
S	—*		—*		—*		abs.		abs.		—		0·05	
BaO	abs.†		—		trace		abs.		abs.		trace		nil	
SrO	abs.†		—		abs.		trace		trace				nil	
Li_2O	abs.†		—				trace		trace				trace	
Sum	100·53		98·00		99·75		100·18		100·25		100·33		100·43	

* No Pyrites. † Spectroscopic test only.

TABLE II.—NORMATIVE MINERAL COMPOSITION OF THE ROCKS OF WHICH THE ANALYSES APPEAR IN THE PREVIOUS TABLE.

W.67. Orthoclase Sodalite Basalt. Loc.: Tonduron or Spire.	Per cent.	W.40. Corundum Basalt. Loc.: Billy King's Creek.	Per cent.	W.1. Trachy-Andesite. Loc.: Timor Ledges.	Per cent.	W.22. Trachy-Andesite. Loc.: Forked Mountain.	Per cent.	W.222. Phonolite. Loc : Mt. Bingy Grumble.	Per cent.
Orthoclase ...	19·46	Quartz ...	3·12	Zircon ..	0·18	Quartz ...	1·08	Orthoclase ...	37·25
Albite ...	33·01	Orthoclase ...	19·46	Quartz ..	0·84	Orthoclase ...	36·70	Albite ...	46·11
Anorthite ...	11·40	Albite ...	31·44	Orthoclase ...	37·81	Albite ...	38·25	Nephelite ...	6·25
Diopside ...	14·67	Anorthite ...	14·46	Albite ...	38·25	Anorthite ...	10·29	Nosean ...	0·71
Hypersthene ...	5·05	Corundum ...	2·96	Anorthite ..	7·23	Diopside...	1·89	Zircon ...	0·55
Olivine ...	3·07	Hypersthene ...	3·03	Diopside ...	4·30	Hypersthene ...	3·61	Diopside ...	0·71
Magnetite ...	5·34	Hæmatite ...	12·16	Hypersthene ...	4·20	Ilmenite ...	2·28	Wollastonite ...	1·97
Ilmenite ...	6·69	Fluorite ...	0·16	Ilmenite ...	1·37	Magnetite ...	4·87	Ilmenite ...	0·46
Calcite ...	0·70	Titanite ...	9·60	Magnetite ...	4·18	Water ...	1·30	Magnetite ...	5·10
(Water) ..	2·02	Ilmenite ...	1·82	Calcite ...	0·10			Water ...	1·66
(SO_3) ...	0·04	Calcite ..	0·60	Water ...	1·87				
		Water ...	1·37						
Sum ...	101·45	Sum ...	100·18	Sum ...	100·33	Sum ...	100·26	Sum ...	100·77

W.67.	W.40.	W.1.	W.22.	W.222.
Salic Minerals ... 63·87 Femic ,, ... 34 82 $\frac{\text{Sal.}}{\text{Fem.}} < \frac{7}{1} > \frac{5}{3}$ *i.e.*, Class ii. Dosalane. $\frac{\text{Q.L.}}{\text{F.}} < \frac{1}{7}$ ∴ Order 5. Germanare. $\frac{K_2O+Na_2O}{CaO} = \frac{98}{41} < \frac{7}{5} > \frac{5}{3}$ ∴ Domalkalic (Rang 2) $\frac{K_2O}{Na_2O} = \frac{35}{63} < \frac{3}{5} > \frac{1}{7}$ ∴ Subrang 4 Dosodic. Magmatic name: Akerose.	Salic Minerals ... 71·44 Fem. ,, ... 26·77 $\therefore \frac{\text{Sal.}}{\text{Fem.}} < \frac{7}{1} > \frac{5}{3}$ *i.e.*, Class ii. Dosalane. $\frac{\text{Q.L.}}{\text{F.}} < \frac{1}{7}$ Order 5. Germanare. $\frac{K_2O+Na_2O}{CaO} = \frac{95}{52} < \frac{7}{1} > \frac{5}{3}$ Rang 2. $\frac{K_2O}{Na_2O} = \frac{35}{60} < \frac{3}{5} > \frac{1}{7}$ but very near $\frac{3}{5}$ limit. ∴ Subrang 4 Dosodic. Magmatic name: Akerose, close to Monzonose.	Salic Mins. ... 84·31 Femic Mins. ... 14·05 $\therefore \frac{\text{Sal.}}{\text{Fem.}} < \frac{7}{1} > \frac{5}{3}$ Class ii. $\frac{Q}{F} < \frac{1}{7}$ Order 5. $\frac{K_2O+Na_2O}{CaO} = \frac{141}{26} < \frac{7}{1} > \frac{5}{3}$ Rang 2. Monzonase. $\frac{K_2O}{Na_2O} = \frac{68}{73}$ Sodipotassic. Magmatic name: Monzonose.	Salic Minerals ... 86·32 Femic Minerals... 12·65 Class ii. $\frac{Q}{F} < \frac{1}{7}$ Order 5. $\frac{K_2O+Na_2O}{CaO} = \frac{139}{37} < \frac{7}{1} > \frac{5}{3}$ Rang 2. $\frac{K_2O}{Na_2O} = \frac{66}{73}$ Subrang 3. Magmatic name: Monzonose.	$\frac{\text{Salic}}{\text{Femic}} = \frac{90·87}{8·24} > \frac{7}{1}$ Class i. Persalane. $\frac{\text{Lenad}}{\text{Felspar}} = \frac{6·96}{83·36} < \frac{1}{7}$ Order 5. Canadare. $\frac{K_2O+Na_2O}{CaO} = \frac{180}{0} > \frac{7}{1}$ Rang 1 (Peralkalic). $\frac{K_2O}{Na_2O} = \frac{67}{113} < \frac{3}{5} > \frac{1}{7}$ but very near $\frac{3}{5}$ limit. (Dosodic) Subrang 4. Magmatic name: Nordmarkose, very near Phlegrose.

Name : Olivine-Dolerite.

This rock is calcic and has no relation with the alkaline series.

M.1. Loc.: Hilltop, Black Jack Coal Mine, Gunnedah.

This is a holocrystalline, medium-grained dolerite porphyritic in olivine and titaniferous augite. It contains labradorite (lath-shaped), idiomorphic phenocrysts of purplish augite, corroded olivine phenocrysts, idiomorphic grains and phenocrysts of magnetite, and interstitially analcite ` Apatite occurs as an accessory. The isotropic mineral darkens on heating and gelatinises with acid. It is therefore analcite, but appears to be of secondary origin in part at least.

Name : Olivine-Analcite-Dolerite.

The microscopic investigation of the rocks of the Warrumbungle Mountains brings out the following points, namely :—(1) the existence in the district of a complete series of alkaline rocks ranging from acidic comendites to basic sodalite-analcite basalts; (2) the gradation of these rocks into one another; and (3) that in the volcanic period older basic rocks were remelted at depths in various places, and, after being mixed with more acid alkaline magma, rose to the surface.

The alkaline rocks include—

(1) Riebeckite Comendites } *cp.* Anal.
(2) Pantellarites }
(3) Arfvedsonite Trachyte.
(4) Nosean-Leucite Trachytes and Phonolites.
(5) Ægirine Anorthoclase Trachydolerites and Trachytes.
(6) Albite Magnetite Basalt without olivine or augite.
(7) Sodalite and Analcite Basalts, sometimes with melilite and meliphanite (?).
(8) Garnet and Corundum-bearing Basalts, with laavenite and melilite.

A comparison of the chemical analyses with one another and with the mineralogical characters is very instructive.

TABLE I.—CHEMICAL ANALYSES OF ROCKS FROM THE WARRUMBUNGLE MOUNTAINS.

	W.67. Orthoclase-Basalt. Loc.: Tonduron or Spire.		W.40. Corundum-Basalt. Loc.: Billy King's Creek, near Coonabarabran.		W.1. Trachy-andesite. Loc.: Timor Ledges		W. 22. Trachy-andesite. Loc.: Forked Mtn.		W.222. Nosean Phonolite. Loc.: Bingy Grumble Mountain.		W.140. Pseudoleucite Nosean Phonolite Loc.: Berum Buckle Mountain.		W.16. Arfvedsonite Trachyte. Loc.: Timor Rock.	
	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.
SiO_2	51·88	0·865	48·27	0·805	58·95	0·983	58·32	0·972	60·32	1·005	62·42	1·040	65·90	1·098
Al_2O_3	14·20	0·139	18·02	0·176	17·04	0·167	18·04	0·176	18·32	0·179	17·69	0·174	16·74	0·164
Fe_2O_3 ...	3·72	0·023	12·06	0·076	2·80	0·018	3·27	0·021	3·55	0·022	2·72	0·017	1·72	0·011
FeO	6·87	0·096	0·90	0·013	4·66	0·065	4·28	0·060	1·96	0·026	2·19	0·031	1·99	0·028
MnO	0·02	} 0·001	0·03	} 0·001	0·05	} 0·001	0·06	} 0·001	0·03		0·08		0·06	
NiO	0·04		0·04		0·01		trace		0·05	} 0·001	trace	} 0·001	0·01	} 0·001
CoO	abs.	—	trace	—	abs.	—	abs.	—	trace		abs.		trace	
MgO	4·62	0·115	1·17	0·029	0·57	0·014	0·58	0·014	0·01	0·001	0·20	0·005	0·06	0·002
CaO	6·36	0·114	6·06	0·109	2·49	0·045	2·52	0·045	1·12	0·020	1·53	0·027	0·09	0·002
Na_2O	3·93	0·063	3·73	0·060	4·51	0·073	4·52	0·073	7·01	0·113	5·93	0·096	6·35	0·103
K_2O	3·27	0·035	3·33	0·035	6·39	0·068	6·21	0·066	6·25	0·067	6·29	0·067	5·77	0·062
H_2O (100°C −)	0·58	} 0·117	0·85	} 0·078	0·59	} 0·106	0·35	} 0·072	0·35	} 0·094	0·24	} 0·050	0·27	} 0·039
H_2O (100°C +)	1·44		0·52		1·28		0·95		1·31		0·69		0·43	
CO_2	0·29	0·007	0·30	0·007	0·06	0·001	—	—	trace		abs.		abs.	
TiO_2	3·54	0·044	4·87	0·061	0·76	0·009	1·25	0·015	0·25	0·003	0·35	0·005	0·25	0·003
ZrO_2	—	—	0·04	—	0·17	0·001	—	—	0·38	0·003	0·20	0·002	0·29	0·002
P_2O_5	trace	—	trace	—	abs.	—	pre.n.d.		abs.		abs.		abs.	
Cl	trace	—	trace	—	trace	—	—		abs.		—		trace	
F	—	—	0·11	0·005	abs.	—	—		—		—		0·16	0·008
SO_3	0·04	—	abs.	—	trace	—	—		0·11	0·001	0·05	0·001	abs.	
S	—*	—	abs.	—	abs.	—	—*		abs.*		abs.*		abs.*	
BaO	abs.		abs.		abs.		abs.		abs.†		abs.†		abs.†	
SrO	abs.		abs.		abs.		abs.		abs.†		abs.†		abs.†	
Li_2O	—		abs.		abs.		abs.		abs.†		abs.†		abs.†	
Sum... ...	100·80		100·30		100·33		100·35		101·02		100·58		100·09	

* No Pyrites. † Spectroscopic test only.

TABLE I.—CHEMICAL ANALYSES OF ROCKS FROM THE WARRUMBUNGLE MOUNTAINS *(continued)*.

	W.38. Arfvedsonite-Ægirine Trachyte. Loc.: Timor Rock.		W.127. Porphyritic Soda Trachyte. Loc.: N.E. of Berum Buckle.		A. Trachyte. Loc.: Mt. Flinders, nr. Ipswich, Queensland (Analyst, H. I. Jensen).		B. Trachyte. Loc.: Parish of Dungarry, near Dubbo, N.S.W. (Analyst, B. White, Rec. Geol. Surv. N.S.W.)		C. Trachyte. Loc: The Canoblas, nr. Orange, N.S.W. (Analyst, B. White, Rec. Geol. Surv. N.S.W.)		D. Trachyte. Loc.: Wantialable Ck., Warrumbungle Mts. (Analyst, J. C. H. Mingaye, Rec Geol. Surv. N.S.W. iv. p. 116, 1895).		E. Ægirine Trachyte. Loc.: Mount Jellore, Mittagong. (Analyst, D. Mawson, Journ. Roy. Soc., N.S.W., xxxvii.).	
	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.
SiO_2	63·82	1·064	60·73	1·012	60·58	1·010	67·68	1·128	72·06	1·201	74·12	1·235	66·68	1·111
Al_2O_3	17·85	0·175	18·16	0·178	18·06	0·177	13·99	0·137	13·86	0·136	12·39	0·122	14·63	0·143
Fe_2O_3	2·75	0·017	4·63	0·029	3·05	0·019	3·20	0·020	1·90	0·012	0·31	0·002	2·18	0·014
FeO	1·67	0·024	0·20	0·003	1·38	0·019	1·98	0·028	1·71	0·024	0·21	0·003	2·31	0·032
MnO	0·04		0·10		0·04		0·02		0·07		trace		0·49	0·007
NiO	abs.	} —	trace	} 0·001	0·07	} 0·002	abs.	—	abs.	} 0·001	—		—	
CoO	abs.		trace		trace		abs.		abs.		—		—	
MgO	0·06	0·002	0·31	0·008	0·23	0·006	0·34	0·009	0·19	0·005	0·42	0·010	0·30	0·007
CaO	0·59	0·011	0·10	0·002	1·74	0·030	0·84	0·014	0·18	0·004	0·30	0·005	1·88	0·034
Na_2O	7·13	0·115	4·88	0·079	5·01	0·081	5·30	0·085	5·84	0·094	3·22	0·052	6·12	0·098
K_2O	5·51	0·059	6·21	0·066	6·87	0·073	4·87	0·052	3·69	0·039	5·07	0·054	4·02	0·043
H_2O (100°C –)	0·66	} 0·050	0·72		0·99	} 0·106	0·65	} 0·094	0·21	} 0·028	2·22	} 0·239	0·38	} 0·067
H_2O (100°C +)	0·20		1·33	} 0·117	0·90		1·05		0·33		2·10		0·83	
CO_2	abs.		trace		—		0·02	—	0·03	0·001	—	—	0·05	0·001
TiO_2	0·25	0·003	0·60	0·008	0·83	0·010	0·20	0·003	0·12	0·001	—		0·20	0·003
ZrO_2	—		—		—		abs.		abs.		—		trace	
P_2O_5	abs.		abs.		—		0·04		0·06		—		0·28	0·002
Cl	trace		0·03		—		trace		trace		—		0·03	
F	—		—		—		—		—		—		—	
SO_3	—		—		trace		abs.		abs.		trace		trace	
S	—*		—*		—*		abs.		abs.		—		0·05	
BaO	abs.†		—		trace		abs.		abs.		trace		nil	
SrO	abs.†		—		abs.		trace		trace				nil	
Li_2O	abs.†		—				trace		trace				trace	
Sum	100·53		98·00		99·75		100·18		100·25		100·33		100·43	

* No Pyrites. † Spectroscopic test only.

Table II.—Normative Mineral Composition of the Rocks of which the Analyses appear in the Previous Table.

W.67.

Orthoclase Sodalite Basalt.

Loc.: Tonduron or Spire.

	Per cent.
Orthoclase	19·46
Albite	33·01
Anorthite ...	11·40
Diopside	14·67
Hypersthene ...	5·05
Olivine	3·07
Magnetite ...	5·34
Ilmenite	6·69
Calcite	0·70
(Water)	2·02
(SO_3)	0·04
Sum	101·45

Salic Minerals ...	63·87
Femic ,, ...	34 82

$\frac{\text{Sal.}}{\text{Fem.}} < \frac{7}{1} > \frac{5}{3}$

i.e., Class ii. Dosalane.

$\frac{\text{Q.L.}}{\text{F.}} < \frac{1}{7}$

∴ Order 5. Germanare.

$\frac{K_2O + Na_2O}{CaO} = \frac{98}{41} < \frac{7}{5} > \frac{5}{3}$

∴ Domalkalic (Rang 2)

$\frac{K_2O}{Na_2O} = \frac{35}{63} < \frac{3}{5} > \frac{1}{7}$

∴ Subrang 4 Dosodic.

Magmatic name: Akerose.

W.40.

Corundum Basalt.

Loc.: Billy King's Creek.

	Per cent.
Quartz	3·12
Orthoclase ...	19·46
Albite	31·44
Anorthite ...	14·46
Corundum ...	2·96
Hypersthene ...	3·03
Hæmatite ...	12·16
Fluorite	0·16
Titanite	9·60
Ilmenite	1·82
Calcite	0·60
Water	1·37
Sum	100·18

Salic Minerals ...	71·44
Fem. ,, ...	26·77

∴ $\frac{\text{Sal.}}{\text{Fem.}} < \frac{7}{1} > \frac{5}{3}$

i.e., Class ii. Dosalane.

$\frac{\text{Q.L.}}{\text{F.}} < \frac{1}{7}$

Order 5. Germanare.

$\frac{K_2O + Na_2O}{CaO} = \frac{95}{52} < \frac{7}{1} > \frac{5}{3}$

Rang 2.

$\frac{K_2O}{Na_2O} = \frac{35}{60} < \frac{3}{5} > \frac{1}{7}$

but very near $\frac{3}{5}$ limit.

∴ Subrang 4 Dosodic.

Magmatic name: Akerose, close to Monzonose.

W.1.

Trachy-Andesite.

Loc.: Timor Ledges.

	Per cent.
Zircon	0·18
Quartz	0·84
Orthoclase ...	37·81
Albite	38·25
Anorthite ..	7·23
Diopside	4·30
Hypersthene ...	4·20
Ilmenite	1·37
Magnetite ...	4·18
Calcite	0·10
Water	1·87
Sum	100·33

Salic Mins. ...	84·31
Femic Mins. ...	14·05

∴ $\frac{\text{Sal.}}{\text{Fem.}} < \frac{7}{1} > \frac{5}{3}$

Class ii.

$\frac{\text{Q}}{\text{F}} < \frac{1}{7}$ Order 5.

$\frac{K_2O + Na_2O}{CaO} = \frac{141}{26} < \frac{7}{1} > \frac{5}{3}$

Rang 2. Monzonase.

$\frac{K_2O}{Na_2O} = \frac{68}{73}$ Sodipotassic.

Magmatic name: Monzonose.

W.22.

Trachy-Andesite.

Loc.: Forked Mountain.

	Per cent.
Quartz	1·08
Orthoclase ...	36·70
Albite	38·25
Anorthite ...	10·29
Diopside... ...	1·89
Hypersthene ...	3·61
Ilmenite	2·28
Magnetite ...	4·87
Water	1·30
Sum	100·26

Salic Minerals ...	86·32
Femic Minerals...	12·65

Class ii.

$\frac{\text{Q}}{\text{F}} < \frac{1}{7}$ Order 5.

$\frac{K_2O + Na_2O}{CaO} = \frac{139}{37} < \frac{7}{1} > \frac{5}{3}$

Rang 2.

$\frac{K_2O}{Na_2O} = \frac{66}{73}$ Subrang 3.

Magmatic name: Monzonose.

W.222.

Phonolite.

Loc : Mt. Bingy Grumble.

	Per cent.
Orthoclase ...	37·25
Albite	46·11
Nephelite ...	6·25
Nosean	0·71
Zircon	0·55
Diopside	0·71
Wollastonite ..	1·97
Ilmenite	0·46
Magnetite ...	5·10
Water	1·66
Sum	100·77

$\frac{\text{Salic}}{\text{Femic}} = \frac{90·87}{8·24} > \frac{7}{1}$

Class i. Persalane.

$\frac{\text{Lenad}}{\text{Felspar}} = \frac{6·96}{83·36} < \frac{1}{7}$

Order 5. Canadare.

$\frac{K_2O + Na_2O}{CaO} = \frac{180}{0} > \frac{7}{1}$

Rang 1 (Peralkalic).

$\frac{K_2O}{Na_2O} = \frac{67}{113} < \frac{3}{5} > \frac{1}{7}$

but very near $\frac{3}{5}$ limit.

(Dosodic) Subrang 4.

Magmatic name: Nordmarkose, very near Phlegrose.

TABLE II.—CONTINUED.

W. 140. Phonolite. Loc.: near Mount Berum Buckle.	W. 16. Arfvedsonite Trachyte. Loc.: Timor Rock.	W. 38. Ægirine Trachyte. Loc.: Timor Rock.	W. 127. Porphyritic Soda Trachyte. Loc.: N.E. of Berum Buckle.	A Trachyte. Loc.: Mt. Flinders, near Ipswich, Queensland.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Quartz ... .. 1·26	Quartz ... ... 5·40	Quartz ... ... 0·12	Quartz ... ... 7·86	Quartz ... .. 1·50
Orthoclase ... 37·25	Orthoclase ... 34·47	Orthoclase ... 32·80	Orthoclase ... 38·02	Orthoclase ... 40·59
Albite ... ... 48·73	Albite ... ... 53·45	Albite ... ... 60·26	Albite ... ... 41·40	Albite ... ... 42·44
Anorthite... ... 3·06	Hypersthene ... 2·18	Anorthite ... 0·28	Corundum ... 3·37	Anorthite ... 6·39
Nosean ... ... 0·71	Acmite .. ... 0·46	Diopside... ... 1·42	Hæmatite ... 4·64	Diopside... ... 1·68
Diopside ... ... 3·68	Ilmenite ... ... 0·46	Wollastonite .. 0·46	Titanite .. .. 0·39	Magnetite ... 2·09
Magnetite .. 3·94	Magnetite .. 2·32	Ilmenite ... 0·46	Rutile ... ... 0·24	Ilmenite ... ... 1·52
Ilmenite ... ... 0·76	Fluorspar ... 0·16	Magnetite ... 3·94	Ilmenite ... ... 0·30	Hæmatite ... 1·60
Zircon ... ... 0·37	Zircon .. ... 0·36	Water ... ... 0·86	Hypersthene .. 0·93	Water ... ... 1·89
Water ... . 0·93	Excess F. ... 0·07		Water ... ... 2·05	
	Water ... ... 0·70			
Sum .. ... 100·69	Sum ... ... 100·03	Sum .. ... 100·61	Sum ... ... 99·20	Sum ... ... 99·70
$\frac{\text{Salic}}{\text{Femic}} = \frac{91{\cdot}38}{8{\cdot}38}$ Class i. Persalane.	$\frac{\text{Sal.}}{\text{Fem.}} = \frac{93{\cdot}68}{5{\cdot}58} > \frac{7}{1}$ Class 1. (Persalane).	$\frac{\text{Sal.}}{\text{Fem.}} = \frac{93{\cdot}46}{6{\cdot}29} > \frac{7}{1}$ Class i.	$\frac{\text{Sal.}}{\text{Fem.}} = \frac{90{\cdot}65}{6{\cdot}50} > \frac{7}{1}$ Class i.	$\frac{\text{Sal.}}{\text{Fem.}} = \frac{90{\cdot}92}{6{\cdot}89} > \frac{7}{1}$ Class i. Persalane.
$\frac{Q.+L.}{F.} = \frac{1{\cdot}97}{89{\cdot}04} < \frac{1}{7}$ Order 5.	$\frac{Q}{F} = \frac{5{\cdot}4}{87{\cdot}92} < \frac{1}{7}$ Order 5 (Canadare).	$\frac{Q}{F} = \frac{0{\cdot}12}{93{\cdot}34} < \frac{1}{7}$ Order 5.	$\frac{Q}{F} = \frac{7{\cdot}86}{79{\cdot}42} < \frac{1}{7}$ Order 5.	$\frac{Q}{F} = \frac{1{\cdot}5}{89{\cdot}42} < \frac{1}{7}$ Order 5.
$\frac{K_2O+Na_2O}{CaO} = \frac{163}{11} > \frac{7}{1}$ Rang 1 (Peralkalic).	$\frac{K_2O+Na_2O}{CaO} = \frac{165}{0} > \frac{7}{1}$ Rang 1 (Peralkalic).	$\frac{K_2O+Na_2O}{CaO} = \frac{174}{1} > \frac{7}{1}$ Rang 1.	$\frac{Na_2O+K_2O}{CaO} = \frac{145}{0} > \frac{7}{1}$ Rang 1.	$\frac{K_2O+Na_2O}{CaO} = \frac{154}{23} < \frac{7}{1} > \frac{5}{3}$ Rang 2 (Domalkalic).
$\frac{K_2O}{Na_2O} = \frac{67}{96} < \frac{5}{3} > \frac{3}{5}$ (Sodipotassic) Subrang 3.	$\frac{K_2O}{Na_2O} = \frac{62}{103} > \frac{3}{5} < \frac{5}{3}$ but very near $\frac{3}{5}$ limit. Subrang 3 (Sodipotassic).	$\frac{K_2O}{Na_2O} = \frac{59}{115} < \frac{3}{5} > \frac{1}{7}$ Subrang 4.	$\frac{K_2O}{Na_2O} = \frac{66}{75} < \frac{5}{3} > \frac{3}{5}$ Subrang 3.	$\frac{K_2O}{Na_2O} = \frac{73}{81} < \frac{5}{3} > \frac{3}{5}$ Subrang 3 (Sodipotassic).
Magmatic name: Phlegrose	Magmatic name: Phlegrose, very near Nordmarkose.	Magmatic name: Nordmarkose.	Magmatic name: Phlegrose.	Magmatic name: Pulaskose.

TABLE II.—CONTINUED.

B
Trachyte.
Loc.: Parish Dungarry, near Dubbo, N. S. W.

	Per cent.
Quartz	16·74
Orthoclase	28·91
Albite	44·54
Diopside	2·94
Wollastonite	0·12
Magnetite	4·64
Ilmenite	0·46
Water	1·70
Sum	100·05

$$\frac{Sal.}{Fem.} = \frac{90·19}{8·16} > \frac{7}{1}$$

Class i.

$$\frac{Q}{F} = \frac{16·74}{73·45} < \frac{3}{5} > \frac{1}{7}$$

Order 4. Brittanare.

$$\frac{K_2O + Na_2O}{CaO} = \frac{137}{13} > \frac{7}{1}$$

Rang 1. Liparase.

$$\frac{K_2O}{Na_2O} = \frac{52}{85} > \frac{3}{5} < \frac{5}{3}$$

near $\frac{3}{5}$ limit.

Subrang 3. Sodipotassic.

Magmatic name: Toscanose.

C
Trachyte.
Loc. The Canoblas, near Orange, N. S. W.

	Per cent.
Quartz	22·74
Orthoclase	21·68
Albite	49·25
Anorthite	0·56
Diopside	0·49
Hypersthene	1·95
Magnetite	2·78
Ilmenite	0·15
Water	0·70
Sum	100·30

$$\frac{Sal.}{Fem.} = \frac{94·23}{5·37} > \frac{7}{1}$$

Class i. Persalane.

$$\frac{Q}{F} = \frac{22·74}{71·49} < \frac{3}{5} > \frac{1}{7}$$

Order 4. Brittanare.

$$\frac{K_2O + Na_2O}{CaO} = \frac{133}{4} > \frac{7}{1}$$

Rang 1. Liparase.

$$\frac{K_2O}{Na_2O} = \frac{39}{94} < \frac{3}{5} > \frac{1}{7}$$

Subrang 4.

Magmatic name: Kallerudose.

D
Trachyte.
Loc.: Wantialable Creek, N. S. W.*

	Per cent
Quartz	34·3
Orthoclase	30·6
Albite	27·2
Anorthite	1·4
Corundum	0·9
Hypersthene	1·2
Magnetite	0·5

Class i. Persalane.
Order 4. Brittanare.
Rang 1. Liparase.
Subrang 3. Sodipotassic.
Magmatic name: Liparose.

* See Chem. Analyses of Igneous Rocks by H. S. Washington, Professional Paper No. 14, U.S. Geol. Surv.

E.
Jellore Trachyte.
Journ. Roy. Soc. N. S. Wales, Vol. xxxvii.

	Per cent.
Quartz	12·42
Orthoclase	23·91
Albite	51·35
Anorthite...	0·56
Diopside	6·23
Hypersthene	0·26
Magnetite	3·25
Ilmenite	0·46
Pyrite	0·10
Apatite	0·67
Water	1·21
Sum	100·42

Class i.
Order 4.
Rang 2.
Subrang 3.
Magmatic name: Toscanose.

Discussion of the Analyses.

The chemical analyses appearing in Table i., with the exception of those which are inserted for comparison (A to E), were carried out by myself in the research laboratory of the Chemical Department, Sydney University; and I desire to express my thanks to Professor Liversidge, M.A., F.R.S., etc., and Mr. Schofield, A.R.S.M., for putting at my disposal the apparatus necessary.

The exigencies of time did not permit me to make duplicate analyses. Though several of my analyses sum up below or above the limits of first-class work, none of them are so inferior as not to be useful for comparison.

The reader is recommended to compare the composition of the Warrumbungle Mountain rocks with the analyses of the trachytes from the Glass House Mountains, Q.,* from Mittagong, N.S.W.,† from the Mount Macedon district, Victoria,‡ and from the Otago Peninsula.§

Special Notes.

W.67. This rock was analysed to verify chemically the conclusion arrived at by microscopic examination, that this orthoclase basalt and the trachydolerites allied to it (*e.g.*, W.64) were formed by a mixture of magmas. The CaO and MgO are too low and the alkalies (especially K_2O) are too high to permit the rock to be referred to the basalts. Nor can it be referred to the trachydolerites, as the Al_2O_3 percentage is too low. The alkaline basalt from the Blow Hole Flow near Kiama‖ is closer to it in chemical composition than any other rock of basaltic appearance of which I can find analytical records. The norm is that of "akerose." The rocks which usually have this composition,

* H. I. Jensen, These Proceedings, 1906, Part i.

† D. Mawson, Journ. Proc. Roy. Soc. N. S. Wales, Vol. xxxvii.

‡ Quoted by Prof. Gregory, Proc. Roy. Soc. Victoria, Vol. xiv., Pt.2.

§ P. Marshall, 'The Geology of Dunedin,' Q.J.G.S., Vol. lxii., 1906.

‖ 'Geology of the Kiama-Jamberoo District,' Records Geol. Surv. N. S. Wales, Vol. viii., Pt.1.

namely, the akerites and many monzonites, are of an entirely different physical appearance and habit (compare "Akerite," N.15, Nandewar Mountains, H. I. Jensen in litteris). The minerals of the norm are in close agreement with those actually observed in the mode, a fact due to orthoclase and albite of a trachytic magma having mixed with augite, olivine, and basic felspar of a partially fused doleritic magma whereupon the whole mass has consolidated.

W.40. Corundum Basalt is a rock which contains minerals which by optical means alone could not be determined with accuracy. These were—(1) A black, lustreless, usually opaque mineral, which in very thin slices appeared occasionally to be translucent and bluish. It was wholly isotropic. The analysis shows that it cannot be spinel or magnetite, and that it must be corundum and sapphire. This determination bears out the Rev. J. M. Curran's theory that our sapphires are derived from basalt. (2) Yellow needles terminated by pyramids. This mineral was considered to be wöhlerite or laavenite. The high TiO_2 percentage and the presence of ZrO_2 make the occurrence of laavenite highly probable, and the titanic acid is so high that the allied minerals rosenbuschite and rinkite are probably also present.

The norm differs very considerably from the mode. The ground-mass is very readily gelatinised with dilute acid, indicating the presence of a felspathoid which probably contains most of the K_2O.

In the trachy-andesites, W.1 and W.22, we again notice that the mode is very different from the norm. This is, of course, because the hypersthene and diopside molecules are incorporated in the ægirine-augite. In W.22 the TiO_2 percentage is higher than in W.1, a fact which verifies the determination of pseudo-brookite in the rocks of Nandi Mountain and The Forked Mountain. The norm of the trachyte-andesites calculates to monzonose. Rosenbusch (in 'Gesteinlehre') describes such rocks under the name keratophyre. This designation is, however,